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GEOLOGIC FORMATIONS *VERSUS* LITHOLOGIC INDIVIDUALS.

A RECENT article in this JOURNAL by Bailey Willis, entitled "Individuals of Stratigraphic Classification,"[1] renews a discussion of both fundamental and practical questions coming before the geologist engaged in areal mapping, which has gone on since the earliest days of geology and seems destined to go on indefinitely. The writer recognizes that Mr. Willis voices the beliefs of many geologists, among them being Edwin C. Eckel, whose still more recent contribution to the discussion[2] indorses the statements by Mr. Willis. But there is another and fundamentally different view of the matter, also held by many working geologists, and the writer wishes to present a few remarks from that standpoint. It is desired particularly to discuss the proposition maintained by Mr. Willis that the proper cartographic units, representing "Individuals of stratigraphic classification," are "lithologic individuals," discriminated by the geologist solely on lithologic characters. Mr. Willis cites the rules of the United States Geological Survey, established some twelve years ago, concerning cartographic units, upholding them in their most literal interpretation. But the writer does not

[1] JOUR. GEOL., Vol. IX, p. 557.

[2] "The Formation as the Basis for Geologic Mapping," JOUR. GEOL., Vol. IX, p. 708.

now wish to touch upon the cited rules or actual practice of the government Survey, since the question of revising those rules is, at the time of writing, under consideration by a committee appointed by the Director. There is ample room, however, for a discussion of the natural objects of a geological map and an analysis of the actual conditions facing the geologist endeavoring to express geologic facts upon a map. The writer aims to do this in no controversial spirit, making frequent reference to the articles cited simply because they are the latest expressions of a view held by many geologists.

Before entering into the discussion of the geological problem, the writer wishes to express a protest against a tendency of the time to impoverish the language of ordinary speech by the appropriation of many of its commonest terms, having universally adopted and understood meanings, to technical and specific purposes. This is found in other languages than our own, and in the literature of other sciences than geology, but for both general and specific reasons some of the terms necessarily employed in this discussion may be mentioned as cases in point. When such terms as "group," "division," "series," "period," and "formation" are appropriated for special and limited uses the geologist is decidedly hampered in his general discussions and obliged either to employ unusual terms for common concepts, or to carefully and repeatedly explain his use of terms as he goes along. That restricted definitions of some of the terms mentioned have the sanction of the International Congress of Geologists merely makes the situation worse. The importance of this matter appears not to be limited to the indirectness of statement forced upon a writer in discussing the commonest points of geology and to the inconvenience of so doing, for unless a writer does explain his use of terms there is often uncertainty as to his meaning, and the unnatural limitation imposed may well act at times as an obstacle to clear thinking.

It seems desirable to refer to this matter because the uses of the word "formation" and of the expression "lithologic individual" or "unit" by Messrs. Willis and Eckel, in their cited

articles, undoubtedly obscure the meaning of their discussions. It is true that their usages are in accordance with the cited definitions of the United States Geological Survey regarding cartographic units, and that the usage is now becoming common, so that no special criticism of their course can be intended in this reference. But as will appear, the writer's conception of the geologic formation is of something which does not receive recognition in the articles by Messrs. Willis and Eckel, while we are all nominally discussing the same thing, namely: the desirable and practicable scope of the geological map and the nature of the problem presented to the geologist in making such a map. In all frankness the writer is unable to decide to what extent the conception of the geologic formation entertained by him is actually coincident with that of the nominally restricted "formation" or "lithologic individual" in the minds of Messrs. Willis and Eckel, although it is clear that, in spite of the definitions they profess to follow, some other factors than those of the definitions are really there.

Mr. Eckel entitles his article, "The Formation as the Basis for Geologic Mapping." Under the restricted technical use of the word he soon states that he means "lithologic unit," something discriminated and defined solely on lithologic characters. But in the discussions of Mr. Eckel and Mr. Willis, and of other writers professedly dealing with a formation thus defined, there is continual evidence that to some extent other factors enter into their idea of what they designate a "lithologic unit," such as stratigraphic continuity, even if accompanied by change of lithologic character. The terms "lithologic individual" or "unit" used in defining *formation*, or given as practically synonymous with it, refer in their common or apparent meaning to a *rock*, one of the units treated by the systematic science of petrography. Mr. Willis constantly refers to the mapping of rocks. The definition of the "formation" as a "lithologic individual" lays stress on the idea that it is a result of continuity of physical conditions, securing to the sandstone or limestone mass its unity of lithologic character. But in the acknowledgment of

the fact that fossils may be necessary to "identify" this *lithologic unit* is evidence of the entrance of other ideas than those of lithologic characters into the underlying conception of the *formation*. Stratigraphic position, continuity—giving it structural importance—and something of age, relatively or absolute, are clearly there but unexpressed.

The writer's conception of the geologic formation is the broad and general one, commonly entertained before the restricted use of the word "formation" was advocated—and still held, he is happy to believe, by many geologists; it is of something entirely unsystematic. The known portion of the earth consists of rock masses of various modes of origin, in which the record of earth history lies. In considering the geology of any portion of the earth, one naturally separates these rock masses into individuals or groups, large or small, for the purpose of deciphering or expressing geology. Each division possesses a certain unity varying in degree or kind according to the point of view. All but the broadest divisions may be properly called geological formations.

Each rock mass assuming importance from the geologist's standpoint stands for many things. It may be viewed from a narrow standpoint and considered to have individuality from the factors of that standpoint only. The lithologic characters may be taken into account and then it is "a lithologic individual;" its faunal contents considered, it may possibly be correct to speak of it as "a faunal unit;" but when it is spoken of as a geologic formation, there should be involved the entire geologic record it contains. Only when the student considers it in its entirety is he entitled to call himself a geologist; otherwise he is but a specialist—a paleontologist, a lithologist, a stratigrapher, or a physiographer. The writer understands the geological map to be a representation of certain geologic formations, selected to express, so far as cartographic limitations permit, the geology of the area covered.

The writer will use the term "geologic formation" in its broad sense and, in courtesy to his colleagues, consider that

they must also conceive of the geological map as more than a map of lithologic individuals could be. Mr. Willis states, with justice, that we are often perplexed to know what the divisions or cartographic units of a map are intended to represent.[1] That is particularly true of formations purporting to be "lithologic individuals," which are actually heterogeneous in lithologic character and do not represent continuity in conditions of deposition. The writer believes that every definition of a geologic formation chosen as a cartographic unit should contain a statement of all the factors determining and justifying its discrimination, with due emphasis on the most important features of each case.

Mr. Willis addressed himself in the cited article to the question "Should geologists map the record of physical conditions or the record of biological conditions—rocks or fossils?" and his answer was: "Both, but with distinctions." The question might be assumed to be broad enough to cover the problem of the geological map if the term "physical conditions" could be interpreted as referring to the general physical development of the earth as recorded in rock masses. But Mr. Willis's whole discussion is directed to maintaining the idea that geology is in such an elementary state of development that our present object must be restricted to mapping "lithologic individuals, while our associates, the paleontologists, distinguish the faunal units of stratigraphy."[2] "The record of physical conditions" must then be regarded as referring only to the conditions causing the lithologic characters, by which the so-called "lithologic individuals" are to be discriminated. As already stated, the writer believes that geologists should map *geologic formations*, not rocks or fossils. A map of lithologic individuals, discriminated on the restricted grounds advocated by Mr. Willis, is not entitled to be called a geological map; it is a *lithological map*, pure and simple.

The question under discussion is really, "What should a geological map represent?" The writer's answer is that it should represent as much of the geologic development of the earth

[1] *Loc. cit.*, p. 557. [2] *Loc. cit.*, p. 569.

recorded in the area covered as is practicable. To that end its cartographic units must be established with regard to *all* the facts and conditions of the case, and not upon the restricted basis of any part of those facts. Of course this discussion does not refer to the mechanical limitations of map-making, nor to local maps of large scale designed for some special purpose, but to the problem involved in the mapping of a geologic province on a scale similar to that of the *Atlas of the United States Geological Survey*.

This idea of the geological map is based upon the consideration that geology is the broad science of the earth, viewing it as originating in a manner still a matter of hypothesis, as developing through a long succession of changes, from that uncertain state to the present conditions. Geology deals with all the processes involved, their modes of operation, and the results. Development implies a succession of events, a series of changes, a history, and so some conception of geological chronology is inseparable from the discussion of rock masses as *geologic formations*. The available record of earth history prior to the present time is in the rock masses and their relations to each other. Geological mapping, therefore necessarily consists chiefly in representing the distribution of rock masses. The map will fulfill the purpose of expressing geologic development in proportion as the units of representation are discriminated with reference to *all the record* contained in them. If the cartographic units are determined by consideration of only a part of the information which may be used, the map will be restricted, and unnecessarily so.

It seems to the writer that the proposition to map "lithologic individuals," and to call the result even by courtesy a geological map, ignores very largely the fundamental distinction between the *rock*, as an object of certain petrographic character, and the *geologic formation*, a mass of importance in the crust of the earth, and containing far more than the record of physical conditions controlling its formation. The separation of petrography from structural geology was made nearly one hundred

years ago, and to that step as much as to the recognition of paleontology is due the present science of structural and historical geology. Perhaps Mr. Willis did not intend to use the term "rock" in its natural and limited sense, yet the proposition to make a geologic map a representation of "lithologic individuals" discriminated solely on "lithologic character" affords no basis for the supposition that he had in mind the idea of the geologic formation, properly speaking. To advocate such a map is practically no advance upon the time of John Macculloch, who in 1821 published his celebrated *Geological Classification of Rocks*, etc., having stratigraphy in mind, and with no idea of the necessity for a science of rocks. There is in the idea, however, a curious combination of this old-time misconception with an element of the so-called "new geology," which is chiefly occupied with physical conditions under which the earth is sculptured and detrital rocks are formed, although this branch of geology is no more *new* than any other.

From the statements by Mr. Willis that he "by no means advocates disregard of fossils in the *identification of formations;*" that "there is a difference between using fossils as one of several means of *identification* and employing them as *essential* characters;" and that "they should not set limits in the discrimination of formations" (*italics* the present writer's), it appears that there is an unrecognized or imperfectly expressed acknowledgment that the Jenkinsville sandstone, for example, is more than a sandstone exposed in a ledge at Jenkinsville — that it is, in fact, a geologic formation. But the writer confesses that he does not fully understand the use of the terms "identify" and "essential" in these quotations. Apparently Mr. Willis would *discriminate* and *define* "formations" by their lithologic characters as the only "essential" factors, but still realizes that such formations may not be *recognizable* by their "essential" characters and that the accidental or unessential factors, fossils, may then be useful or necessary. How and where would Mr. Willis express the facts concerning certain fossils in relation to the Jenkinsville sandstone which warranted or made possible their use in *identifying*

that "lithologic individual"? If any object be defined as having certain essential characters and it develops from experience that the object cannot always be identified by those characters, or, conversely, if it be found necessary to use supposedly unessential factors in its identification, there is something logically wrong in the conception of the object.

Viewing sedimentary formations as documents of geological history, the deciphering of their complete record of events requires consideration of many things. The most striking fact in many cases is the lithologic character of the formation. From this character the mass receives its petrographic designation, and from it some of the conditions of sedimentation and of local physiography at the time of deposition may be inferred. Often these factors permit further inferences as to the events preceding or following the deposition of a given stratum. But all the strictly lithologic characters have no chronologic significance. A sandstone, shale, conglomerate, or limestone may have been deposited at any time from the Algonkian to the Tertiary. As Mr. Willis clearly expresses it, "we now know that the physical characteristics of rocks are repeated from time to time, and are diverse in different provinces at the same time, and that therefore they do not afford criteria of contemporaneous deposition.[1] Much more of the record of earth development may be found in the sedimentary deposit, however, if other data are considered. Such deposits consist usually of chemical precipitates, fragments of older rocks, or of organic remains.

Lithologically the source of materials for a clastic rock may be of no consequence. A conglomerate is a conglomerate, whatever the age may have been of the rocks which were destroyed to furnish sand or pebbles. But viewing the conglomerate as a geologic formation, it is of great importance to note what earlier rock formations are represented in any given case. Even a single pebble or bowlder may throw more light upon the chronologic position of the conglomerate, and the

[1] *Loc. cit.*, p. 557.

extent and importance of the erosion which exposed the rock of that pebble, than is afforded by all other data combined. Two conglomerates in close proximity, and so situated at the locality where they are exposed that they seem to belong to the same general period of sedimentation, may possess in their pebbles evidence of events of great importance in the interval imperfectly represented by the stratigraphic line between them.

Lithologically a shell limestone is one largely composed of shells, and a coal of certain properties is bituminous coal, whatever shells or plants, respectively, may have produced the rocks in question. But viewing the coal beds and limestones, or other fossiliferous strata, as geologic formations, not "lithologic units," the significance which paleontology shows may be attached to the particular fossils found in a given case is of great importance. The record here referred to is not that of life history, but of earth history. The fossils of a "lithologic individual" may be the most significant characters it contains bearing upon its age, the extent and importance of earth development in the epoch preceding its deposition, the characters of the waters in which it was formed, and the climatic conditions of the time. From the standpoint of the investigator striving to make out the full significance of a sedimentary deposit, a constituent pebble of a recognizable older rock of known structural position is a feature possibly equal in importance to a shell, a bone, or a plant, of certain paleontologic character. Both are fossils, in a sense.

The mode of origin and the characteristic features of igneous rocks render the evidence of geologic history to be obtained from them limited as compared with that which may be derived from sedimentary formations. But it appears to the writer that much more effort should be made to read these records and to represent the information obtainable on geological maps than is commonly attempted.

The petrographic, or lithologic, character of an igneous rock serves to show its proper systematic position and leads to its

designation. Such characters testify that a magma of certain chemical composition consolidated at the place where a given rock is seen, under conditions producing the mineralogical and textural result observed. What some of these conditions were can be inferred, and something of the eruptive history may be read in the petrographic characters. But these features give but little more data bearing upon geological chronology than do those of a sandstone or conglomerate. To be sure, one may be more warranted in assuming that an observed granite is of ancient formation, or that a leucite-bearing lava is of Tertiary age, than one would be in concluding that a sediment of almost any common lithologic character belonged in any particular part of the stratigraphic column. This is, however, due more to the circumstances of the exposure of an igneous mass than to any known connection between age and petrographic character.

Geologically it is of interest to know whether igneous masses are extrusive or intrusive. Although an indefinite relative age is all that is commonly determinable, there are many instances where the chronologic relation between the eruption of certain magmas and the deposition of certain sediments can be established. In a given province a certain series of eruptions may be visibly connected with a known volcanic center, while other igneous rocks of the same region are clearly independent of that center, and may be demonstrably very different from its products in age.

When any of these, or of other, geologically significant relations of igneous rock masses may be determined, and it is practicable to express them on a geological map, such representation should certainly be attempted. If such relations are ignored the map fails to satisfy the legitimate demands of the geologist for the same reason that a map of sedimentary "lithologic individuals," fails of its full usefulness.

Metamorphic rocks have been derived from all kinds of igneous and sedimentary rocks by a great variety of processes. In numerous cases the derivation of the metamorphic product is

clear and it may be found in association with comparatively unaltered portions of the original mass and exhibiting transition stages. But the great majority of these interesting records of earth history belong to the oldest periods of geologic time of which we have evidence in the rocks, and the nature of the primary mass can never be established. The discrimination and representation of metamorphic rock formations should, however, be intended to express as much as practicable of this phase of earth development.

The belief that a geological map of today must be limited to the exhibition of the distribution of local "lithologic individuals or units," seems to the writer not only inconsistent with the true conception of the object of the geological map but to ignore the known facts of the stratigraphic column. It is now desired to consider a few of the practical problems presented to the areal geologist in the preparation of a geological map.

In the first place, it will be assumed that the terms "lithologic unit" or "individual" and the proviso that "they shall contain between their upper and lower limits either rock of uniform character or rock uniformly varied in character," imply that this unity in character has been derived from actual continuity or regular oscillation of conditions of sedimentation during the epoch in which the formation was deposited. If such implication is not intended, it may be remarked that a map of such units would so effectually obscure geological conditions that it could not be included within the scope of the present discussion. But the writer wishes to assert his belief, on the one hand, that many extensive sections of the stratigraphic column cannot be completely divided into mapable units of the significance above implied, and on the other hand, that the inference of continuity of conditions, suggested by lithologic character alone, must be tested by all available facts of the case to avoid falling into serious error. This belief is based upon the writer's personal experience in the stratigraphic section of the Rocky Mountain province, ranging from the Algonkian to the Tertiary, and upon

his knowledge of some of the experiences of his colleagues in the United States Geological Survey work.

Where lithologic uniformity or regularity in variation of character actually stands for continuity of conditions, as far as existing facts indicate, the writer is as ready as any one to acknowledge that that fact should be recognized on the map, because it represents a fact both of geological history and of local conditions. The local importance of such a formation is surely to be recognized where it does not obscure facts of more fundamental significance. In this belief he has, for example, discriminated and mapped the *Mancos shale* of the Telluride and La Plata quadrangles in Colorado. This Upper Cretaceous formation is nearly two thousand feet in thickness, rests on the Dakota sandstone and embraces strata deposited during the Benton, Niobrara and Pierre epochs, as indicated by fossils occurring near the base and near the top of the shale complex. It is at present a matter of inference that some of the shales of this complex correspond in time of deposition to the strata assigned to the Niobrara formation, as it has been generally discriminated elsewhere in Colorado.

The Ouray limestone of Colorado, first described and named in 1900 by A. C. Spencer,[1] then the writer's assistant, was at first supposed to be wholly of Devonian age. It is nearly three hundred feet in thickness, and while not actually homogeneous is in very large part a limestone formation. Near the center a marked Devonian invertebrate fauna has been found, and above that horizon no persistent line can be drawn on lithologic character. It has been recently ascertained, however, that Lower Carboniferous fossils occur in certain places in the very uppermost layers of this local limestone unit. As study of this formation progresses it is plain that some, and possibly a considerable, thickness of Lower Carboniferous limestone was eroded from its upper portion in the time interval preceding the Upper Carboniferous. In its present partially metamorphosed condition the Ouray limestone seems in large degree a unit of continu-

[1] "Devonian strata in Colorado," *Amer. Jour. Sci.* (4), Vol. IX, p. 125.

ous deposition, from the period represented by the Devonian fauna to that of the Lower Carboniferous. The writer then, for the present, accepts the local lithologic fact, and the absence of an observed explanation for the faunal change, as determining the treatment of the formation as a unit. If in the tracing out of the Ouray limestone it should be found that the inference of continuous sedimentation is incorrect and that a traceable and really sharp line, indicating a stratigraphic break, exists near the center of the apparent unit, the writer would favor an expression of that fact upon the map, if feasible. How that should be done is a matter of detail, from his standpoint. If the break in question should be found to represent a period of orogenic disturbance, with overlap of the Lower Carboniferous member, the desirability of expressing that fact wherever the limestone complex is found would be great. But for the region in which the apparent lithologic unit is now known it may be best that it should receive a single name, even if its lower and upper members be designated, respectively, as Devonian and Carboniferous.

Another phase of the problem of establishing cartographic units may be illustrated by the stratigraphic section of the Rico Mountains, in southwestern Colorado, studied by a party in charge of the writer, which was cited by Mr. Willis[1] as an example of unwarranted departure from the rule requiring that lithologic character alone should be used in discriminating "formations." The section in question has a total thickness of about 4,500 feet, and lithologically presents a series of irregularly alternating conglomerates, sandstones, shales, limestones, marls, and all manner of transition beds, few of which exceed one hundred feet in thickness. There are probably fifty or sixty lithologic divisions which might be established and traced for some distance, most of which would have a fair degree of lithologic uniformity. Only by such detailed mapping can the conditions of deposition be graphically expressed. Any grouping of unlike units obscures that expression. There is no "lithologic individ-

[1] *Loc. cit.*, p. 561.

ual" except the comparatively thin bed. The mapping of these lithologic units, however, would involve topographic maps of large scale and great accuracy, and an expenditure of time which, in view of the present condition of the survey of Colorado, renders such detailed work inadvisable. But assuming that the mapping of each "lithologic unit" were feasible and that it had been carried out, without some grouping of these units the map would be merely a lithological map. It seems improbable that even Mr. Willis would be content with such a map, in view of the range of this section. The problem of grouping the units is, however, the same as that of dividing the entire section for the purpose of representing the main ascertainable facts of geologic development.

It is known by fossil and structural evidence that the section in question embraces practically all that is present in the region of the Carboniferous (including Permian) and Triassic systems. In earlier reconnoissance surveys and reports touching the province, this general distinction has been drawn. The upper half, which has a reddish color, has been distinguished as the "Red Beds" of assumed Triassic age; the lower half, which has no prevalent reddish color, has been referred to the Carboniferous from scanty fossil evidence. In the recent areal work of the geological survey in charge of the writer, it has been found that the reddish color line is both indefinite, through gradations, and variable as to horizon. For any but crude reconnoissance work the red color line is not a practical guide. Through careful study of the section in several quadrangles, it has been found that the lower two thousand feet of the complex contains in its limestones and shales a persistent Lower Carboniferous invertebrate fauna. While extensive collections have been made from various horizons, the paleontological opinion rendered by Mr. G. H. Girty is to the effect that no faunal groups are indicated warranting a suggestion that any particular one of the many planes of lithologic change represents an interval of unrecorded events, or gives grounds for a division, for the expression of correlation with structural members of the Upper Carboniferous

elsewhere known. The actual Triassic age of the upper portion of the "Red Beds" has been established by scanty but significant vertebrate, invertebrate, and plant remains, occurring within a limited vertical range. The problem, alike for the geologist, endeavoring to make an adequate geological map, and for the lithologist, required to express the grouping of the many small lithologic individuals in the structural divisions of the Carboniferous and Triassic systems, is here to find the correct line between them.

In the Rico Mountains it was found that above the complex of two thousand feet of beds characterized by the Lower Carboniferous fauna there was a series of strata about three hundred feet in thickness, generally somewhat reddish in color, sometimes markedly so, containing a fauna described by the paleontologist as distinctly different from that known in the two thousand feet of strata below and as intermediate in character between the Carboniferous and Permian faunas thus far known. The change takes place abruptly, *i. e.*, within fifteen feet. The Permo-Carboniferous fauna occurs in thin limestones through a section containing lithologic members much like strata above or below. Above this series comes an apparently unfossiliferous section of frequent and irregular changes in lithologic character. Many of the strata here are extremely like beds of the complex containing the Permo-Carboniferous fossils.

In the *Report on the Geology of the Rico Mountains* by the writer and A. C. Spencer the heterogeneous group of strata containing the Lower Carboniferous fauna was designated as the "Hermosa Formation;" that containing the Permo-Carboniferous fauna as the "Rico Formation;" and the remainder of the section was provisionally assigned to the "Dolores Formation."[1] The latter formation had already been defined as intended to include the Triassic portion of the heterogeneous "Red Beds" section of the region and apparently including the whole. The object in making the three divisions was to express

[1] WHITMAN CROSS and ARTHUR COE SPENCER, "Geology of the Rico Mountains, Colorado," *Twenty-first Ann. Rept. U. S. Geol. Surv.*, Part II, 1900.

geologic history, though imperfectly. The divisions were not intended to be "faunal divisions" as Mr. Willis states, but *geological divisions*. They were founded primarily on the evidence of fossils, because lithologic character utterly failed to indicate the importance of the events which must have occurred before and after the Rico epoch. The lower line of the Rico formation is accurately determinable in the field so far examined by the relations of a thin black limestone, a thin-bedded series of sandstones, fifteen feet in thickness, above it, and a reddish sandy-looking limestone. The thin black limestone is a guide because it is full of a foraminifer, *Fusulina cylindrica*, common in the Hermosa limestones and absent from the Rico beds; the other limestone because it is crowded with the Permo-Carboniferous fauna. The upper line of the Rico formation, as at present mapped, expresses the fact of the apparent limitation of the Rico fossils. The succeeding strata have been referred provisionally to the Triassic system because no known evidence gives a basis for recognizing the Permian or any other geologic unit expressive of the important events which clearly must have occurred between the Rico epoch and the deposition of the fossiliferous Triassic strata. The fact that a lithologically heterogeneous section must be scrutinized most carefully to detect planes of relative geological importance is well illustrated in this series of "Red Beds" above the Rico formation. The Rico fauna is a marine fauna; the vertebrates and invertebrates of the Triassic beds, one thousand feet above, are fresh water or land forms. No more marine sediments occur in the section of this region until the Upper Cretaceous rocks are reached. It is not now known whether strata of Permian age are present in this section or not. If that question is ever settled it will be on fossil evidence. Ultimately, the knowledge will be acquired indicating further subdivision of this section in order to express the sequence of events so imperfectly recorded in the rapidly and irregularly changing lithologic character of the strata.

The absolute necessity of using fossils in discriminating geologic formations is frequently illustrated in the areal mapping

of Tertiary deposits in the Coastal Plain region, and even in establishing the boundary between Cretaceous and Eocene systems, although that line may represent a stratigraphic break. Thus in the Uvalde quadrangle of Texas Mr. T. Wayland Vaughan describes the uppermost Cretaceous and the adjacent Eocene formations as presenting such complex and rapidly changing lithologic characters, and as so similar in these variations that the stratigraphic line of much significance between them is not determinable except on fossil evidence. From lithologic character one would necessarily conclude that conditions of sedimentation alternated irregularly through the period represented by the section in question and no one line of change would be suggested as of special importance, or at least the one which is of greatest significance would not be indicated. There is, however, a sharp line present, indicated by the fossils of two beds in close proximity, one carrying a Cretaceous fauna, the other Eocene forms, and no single species of either the extensive Cretaceous fauna below, or of the Eocene above, has been found to cross this line. The use of this information in discriminating cartographic units is thus essential to a representation, which is entirely practicable, of important geological facts concerning this quadrangle and the Gulf province to which it belongs.[1]

Another example of the insufficiency of lithologic characters alone as means of discriminating the desirable cartographic units of a province is afforded by the southern Appalachian region. At the time when the areal work of the United States Geological Survey there was in charge of Mr. Willis, he described the conditions as regards the Paleozoic section as follows:

> Thus the Paleozoic sediments are a great complex of lenses of every grade of lithologic character, from pure limestone to conglomerate, and lithologic distinctions cease to be of value except when used as guides in small districts or when variations are traced out by continuous detailed study.[2]

Mr. Willis further explains (in the same place) that as a

[1] "Uvalde folio," *Geologic Atlas of U. S.*, No. 64.

[2] *Tenth Ann. Rept. U. S. Geol. Surv.*, p. 121.

result of this condition it had been decided by Mr. G. K. Gilbert, his predecessor in charge of the work, to establish the cartographic units of each area mapped upon the lithologic characters there displayed. But, as a matter of fact, the section in question contained fossils, and the present excellent representation of the geologic development of the southern Appalachians, afforded by the combined atlas sheets already published, is due in large degree to the use by Mr. Willis's successors of fossils as guides in discriminating proper geologic formations where lithologic characters failed. By the use of fossils important stratigraphic horizons were recognized which had been entirely overlooked so long as local lithologic features were regarded as the only practical means of establishing cartographic units.

The general chronologic scheme of geology has been established to express the evolution of the known portion of the globe. Its foundation lies in the fossils of the rocks, their demonstrated distribution and the evolution they show. At times the paleontologist, engaged in the biological side of the study of fossils, has seemed to believe that the chronologic scheme of geology was established to express the evolution of life upon the earth rather than the evolution of the earth itself. Sometimes the geologist, engrossed in the problems of the "new geology," appears to forget his own rights and to concede to the paleontologist of the narrow view mentioned the correctness of his claim. But in these later days, as the geologist and paleontologist work more and more in harmony, such limitations of view are certainly becoming rarer, and it is more generally recognized that where a common scheme of time divisions fails to adequately express the known facts of earth development and life evolution some new provision is necessary. The ideas upon this subject recently advanced by H. S. Williams[1] seem to the writer to contribute much toward the adjustment of these difficulties. But it is not desired at this time to discuss the

[1] "The Discrimination of Time-values in Geology," JOUR. GEOL., Vol. IX, p. 570.

basis of *time scales*, meaning graduated measures of time involved in either earth or life history. With Mr. Willis, the writer believes that much further investigation is necessary before complete adjustment of the time scales of geology and of paleontology can be made. In that condition lies no ground for the assumption that the geologist may not use paleontologic evidence at any time in accordance with the best knowledge of that time in deciphering the geologic record and in choosing formation units for its cartographic representation. Doctrines of catastrophism and special creation have yielded to the theory of evolution. A precise diagnostic value for a fossil in taxonomy is no longer claimed. But we still have a chronology of geology. We are now better informed than ever before as to the sequence of geologic events and as to the actual value of fossils to the geologist in all his researches.

The knowledge that life has been continuous, that faunas and floras migrate, that shore lines migrate, shows that time divisions of exact synchronous value can never be established upon either faunal changes or lithologic character of sediments alone. What the basis of the future time scale of geology will be cannot now be safely predicted. That is a matter which does not materially affect the problem under discussion.

The task of the geologist mapping a given province is to express the facts of geologic development there. He may know that his stratigraphic divisions are not to be accurately correlated with those of distant provinces. His province has its own history and his units of mapping, call them as you will, are to be discriminated primarily for the practical expression of that history. He knows that in the main the broader correlations with the history of other provinces will hold good, and he should express correlations indicated by all the evidence known.

The fact, now commonly recognized, that some faunas or floras cannot be used to establish the exact time equivalence of the beds containing them, in widely separated areas, does not seem to the writer to in the least warrant the conclusion that all correlation on fossil evidence is at present undesirable or unjustifiable.

Mr. Willis speaks of a faunal map as something desirable:

> When the map of formations [lithologic individuals discriminated without regard to fossils] is made, the way is prepared for the paleontologist to ascertain the number and bounds of the faunal units and to draw the faunal map.[1]

While the writer desires to see a discussion of the object and practicability of such a map from the paleontological standpoint, he desires, with all due diffidence, to make a few comments upon this idea.

A fauna regarded as the aggregate of associated forms living at a certain time or during a certain period of the past, embraces forms which have run their race and are disappearing, a larger number of those which may be said to be enduring, and still others appearing for the first time. Any fauna is, then, an aggregate of forms whose periods of endurance overlap in most complicated manner, not only because they appeared at different times, but because some are persistent and others comparatively ephemeral. Why should the biologist wish to map the distribution of one fauna rather than that of the many others which overlap it? If he desires to express conditions of life during various epochs, the imperfections of the fossil record, the sequence of periods or stages of development, his purpose is adequately met by a geological map.

From another standpoint, there are various contemporaneous faunas, and also a flora, the existence of the last being sometimes overlooked. There are marine, fresh water, and land faunas, vertebrate and invertebrate, living at the same time but only in part represented in any one formation. It would appear that the biological needs for maps of distribution could scarcely be represented on any one "faunal map."

It is an old simile to speak of "the book of nature." Perhaps in no line of scientific investigation is the aptness of this simile more striking than in the field of geology. The rock formations are so many historical documents of varied scope

[1] *Loc. cit.*, p. 560.

and magnitude. Some are like pamphlets, mainly devoted to a single subject; others are monographic in character, either condensed or expanded. A uniform sandstone bed, free from fossils, is a comparatively simple record; a section like the Norwegian "Silurischen Etagen 2 and 3," described by Brögger, is a monograph of many parts and chapters. The thickness of the book is no indication of its scope.

The investigation of the geology of any given area may be described, continuing this similitude, somewhat as follows: The various rock formations spread out over the area must be viewed as historical documents. Each one contains a record of its time, local or provincial, limited or comprehensive in scope and has, also, chapters relating to earlier epochs. Each has usually various parts, and it may be expressive to say that they are written in different languages. The longest chapters may not contain the most important parts of the record. Indeed, if the observer's eyes are not properly trained, he may not realize the presence of the most valuable chapters. Clearly the geologist cannot recognize the essential characters of these documents if he fails either to note the important chapters, or, noting them, is unable to decipher their meaning. For the latter case, however, he may rely on the interpretation of others, provided he gives them opportunity.

The difficulties of these historical studies are greatly increased by the imperfections, or the gaps, in the record. Some records are not in the rocks themselves, but in their relations, as seen. Some volumes are now dismembered, and parts may have been lost. Juxtaposition of leaves in the present relations does not necessarily imply that they belong to a single volume. Chapters on the same phase of history, belonging to various volumes, may be indistinguishable and lie so related that the student who is a specialist in this phase will quite surely group them incorrectly in a single volume if he ignores, or is unable to see, the other chapters, by which their proper relations are indicated. It is the geologist's duty to group the various chapters correctly in parts and volumes, with an appreciation of their broad significance.

The geological map is comparable to a locality index to this mass of records. It shows where the records may be found, and in a measure the proper chronologic arrangement, the character, and the grouping of the works. It is the whole history which the compiler of this index must have in mind. If he presents merely an index to the lithology of the region, he is doing the work of the specialist. Of one thing he may rest assured, namely, that his arrangement and his characterization of the records will be scrutinized by other students, and if his estimate of a given volume is based upon half knowledge, the other chapters will be read by more thorough investigators and the superficial or limited character of his own work pointed out

WHITMAN CROSS.

LOESS WITH HORIZONTAL SHEARING PLANES.

WHILE engaged in field work on Pottawattamie county for the Iowa Geological Survey in the summer of 1900, a peculiar structure in the loess came under my observation. This appeared to me so unique as to merit special notice.

The loess in Pottawattamie county is of the usual western type. It is lighter in color, slightly coarser, and of a more open texture than the loess in the eastern part of Iowa and in Illinois. It is also heavier, and contains a greater number of fossils than the latter. In the east bluffs of the Missouri river it averages not far from a hundred feet in thickness in this county, and occasionally this measure is exceeded. It frequently contains fossils. In the north part of the county, and sometimes also in the south, it rests on a somewhat darker and more ferruginous deposit. This is similar to loess in appearance, but is less calcareous, in places sparsely pebbly, and much less pervious to water, owing to the presence among its particles of an exceedingly fine and silty ochreous ingredient. It resembles in general the "gumbo" which has been described by Leverett[1] as occurring under the loess in some parts of Iowa, Missouri, and Illinois. This gumbo changes downward into the old leached and weathered upper part of the underlying till. Its upper surface is sometimes marked by an old soil horizon.

The peculiar structure noted in the loess involves the horizon where the two formations just described come into contact; the level where the gumbo changes, gradually or abruptly, upward into loess. Perhaps it would be more accurate to say that it affects the top of the gumbo as well as the base of the loess.

Examining closely one day the lower part of the loess in an excavation southeast from the Pierce Street School in Council Bluffs (near the corner of Voorhees street and Franklin avenue), the lower part of the embankment was seen to be laminated, and

[1] *U. S. Geol. Surv., Mon. XXXVIII*, p. 28.

the lamination was apparently quite unlike that which results from sedimentation. To better ascertain the nature of this lamination a block of considerable size was detached and gently split by fracture along the planes of the laminæ. To my astonishment it revealed a surface strongly reminding of some gently fluted

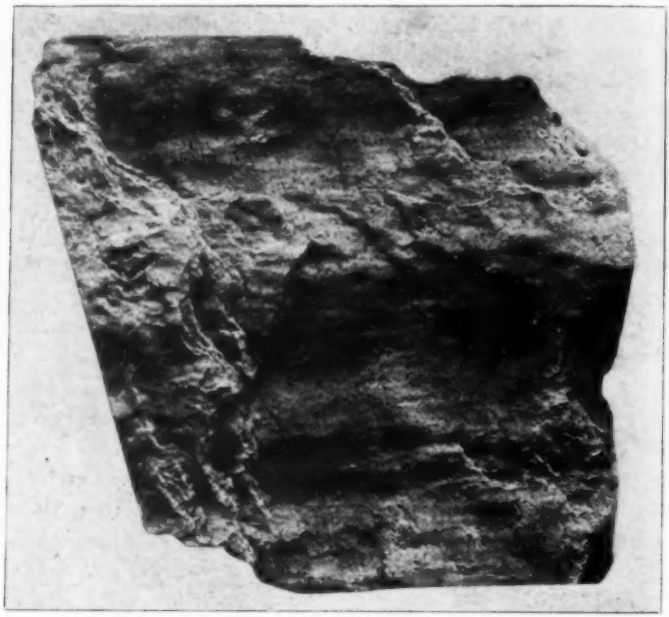

FIG. 1.— Fluted shearing-planes in the loess in Pottawattamie county, Iowa (slightly reduced).

ice-scorings (see Fig. 1). I replaced the lower half of the block and took the bearings, south 60° west and north 60° east. Repeating the observation at several points along the embankment, I found the fluted ridges to pursue strictly the same trend at all places. I also noticed that this trend lay neither in the direction of a tangent nor of a radius to the periphery of the hill in which the excavation was made.

In the continuation of my work in the north half of the county this lamination was observed at a number of other places as follows :

1. *Norwalk township*, in the west bank of the wagon road one-fourth of a mile south of the northwest corner of Section 9. Direction of flutings, S. 65° W.–N. 65° E.

2. *James township*, near the wagon road one-fourth of a mile south of the northwest corner of Section 12. Direction of flutings, S. 20° W.–N. 20° E.

3. *Boomer township*, in the left bank of the wagon road in the north bluff of Pigeon Creek, near the center of the northwest quarter of Section 33. Direction of flutings, S. 70° W.–N. 70° E.

4. *Neola township*, in the bank of the wagon road leading up the hill near the center of Section 24 (on the west border of the town of Neola). Direction of flutings varying from S. 70° W.–N. 70° E. to S. 78° W.–N. 78° E.

5. *Minden township*, in the wagon road near the center of Section 10. Direction of flutings, W. 15° N.–E. 15° S. Also in the north bank of the deep cut of the Chicago, Rock Island & Pacific Railroad about one-fourth of a mile north of the center of Section 21. Direction of flutings, W. 5° N.–E. 5° S. Also in the ditch on the north side of the embankment of the Chicago, Rock Island & Pacific Railroad about one-fourth of a mile east of the northwest corner of Section 19. Direction of flutings, W. 8° N.–E. 8° S. Also in both banks of the railroad cut just south of the bridge across Mosquito Creek in Section 19, east of the town of Neola. Direction of flutings, W. 10° N.–E. 10° S.

6. *Pleasant township*, in the west bank of the Chicago, Rock Island & Pacific Railroad, in the southeast quarter of Section 5. Direction of the flutings, S. 58° W.–N. 58° E. Also in the north bank of the wagon road near the southeast corner of Section 12, and again nearly one mile farther west along the same road. Direction of flutings in both places, S. 78° W.–N. 78° E.

7. *Knox township*, in the west bank of the wagon road just east of the bridge across Biddle Creek, north of the southeast corner of Section 2. Direction of flutings, N. 45° W.–S. 45° E.

8. *Layton township*, in the deep cut of the Chicago, Rock Island & Pacific Railroad, near the west line of Section 13. Direction of flutings, S. 14° W.–N. 14° E.

As seen at these points the laminæ vary from one-eleventh to one-thirtieth inch in thickness, one-sixteenth inch being the most common. There was nowhere any difference in the texture of the material of which they were composed. They are marked off from each other by sharply defined planes, along

which the mass may be caused to split more or less readily. Occasionally layer after layer may be peeled off by the insertion of the blade of a knife in the seams which separate them. In one instance the surfaces exposed in this way were smoothened, as it were, by a thin film of dark ferruginous material which evidently had been deposited by infiltration along the seams separating the layers. The flutings are straight, compound folds in the layers. When the latter are viewed in a section vertical to the trend of the flutings, they appear as parallel, very shallow waves an inch or two in width. On these there is a second parallel system of small folds only about an eighth of an inch wide. These also have a very shallow depth, which barely renders them perceptible. Occasionally the layers wedge out, the seams separating them running together. To one familiar with the appearance of ripples and ripple marks, a glance at the surface of these layers in the loess suffices to show that they have nothing in common with the former. The ridges of ripple marks are never straight. Their opposite slopes are regularly unsymmetrical, always steeper in one and the same direction for successive waves. There is no second series of smaller waves parallel with the larger ones. Ripples are also somewhat uniform in size. They are invariably associated with sorting of coarse and fine materials. In vertical section the flowing curves of ripples constantly intersect. None of these characteristics appear here. The folds and flutings in the loess are straight, it might be said rigidly straight. The slopes of the folds are symmetrical, or irregularly unsymmetrical. There is also a considerable variation in size of the folds. As stated before, there is no sorting by which coarse materials have been separated from the fine. The partings between the layers tend to run parallel. When they do run together it is not with the flowing curves seen in the ripple marks. But an analysis of the difference between the two phenomena really blurs the vividness of the intuitive distinction perceived by direct inspection. The character of the surface exposed when the laminæ are laid bare along their partings is much more like that of slickensides or of

stylolitic joints or of glacial fluting. There is no doubt whatever in my mind that *these partings represent shearing planes and that they have been produced by differential motion of the layers which they separate.*

What may have caused such shearing is a question difficult to answer. Local creeping appears to be the least far-fetched explanation. On steep and high slopes the ground sometimes slowly yields to gravity and moves forward and downward on an inclined plane. The horizontal ingredient in such motion is more or less vertical to the "strike" of the slope. Observations on the trend of these flutings soon brought out the fact that this bore no relation whatever to local or minor topographic features. Their direction maintains itself with only small variations for short distances, and at some places, apparently for miles, irrespective of local topography. Thus at Council Bluffs, in Kane township, in Norwalk, Booner, and Neola townships, the bearings of the flutings are respectively 60°, 65°, 70°, and 75° west of south and east of north. At the latter place, near Neola, it is variable, 70°, 75°, 78° west of south and east of north having been noted within a distance of twenty rods in the west part of the village. East of the town it is 10° north of west. For the next five miles east this direction prevails, three points showing a trend of 8°, 5°, and 20° north of west, all in Minden township. East of this the trend is again to the southwest, except at a point three miles northeast of Avoca, where it is west 45° north and east 45° south. On opposite sides of a hill or of a valley, it seems from some observations that the direction is the same, whether it be parallel, vertical, or at any other angle with the local relief contours.

The general trend of the flutings may be said to be from the northeast to southwest. This generalization is based on observations made at only fifteen localities, which are scattered over a territory thirty-six miles from west to east and fifteen miles from north to south. This seems an insecure and insufficient basis from which to draw the conclusion that the flutings have been produced by general movements of the loess in the direc-

tion indicated. Still this suggests itself as an alternative hypothesis, and it should be kept in mind, pending further investigation. The trends of the flutings are by no means more variable than the trends of ice scorings produced by glacial movements (see Fig. 2).

To account for such a general motion, which conceivably may have been very small, two different hypotheses suggest themselves: (1) Tundra conditions may have prevailed. On a slop-

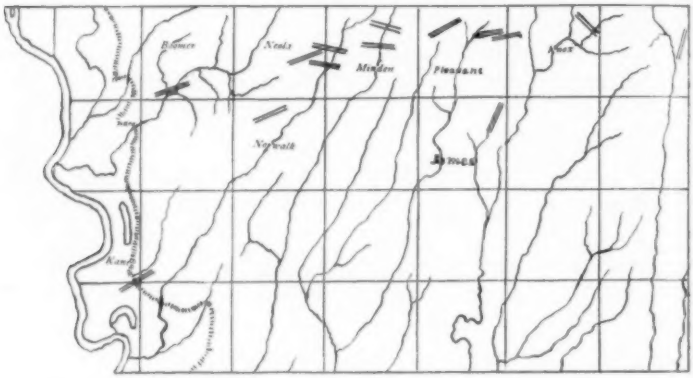

FIG. 2.—Map of Pottawattamie county, Iowa, showing the locations and the directions of flutings observed in the loess.

ing plain the annual temperature changes in a frozen tundra land would be apt to produce extensive creeping in the direction of least resistance, as toward a river. This would, no doubt, result in differential motion near the base of the frozen ground. (2) There may have been glacial conditions. With a sudden onset of arctic climate the area of accumulation of snow might extend far out beyond the margin of the ice pushing out from the region of greatest accumulation, and were the most severe climate not of too long duration, the main continental glacier might come short of extending over all of such extra-marginal and perennial fields of snow. There might then be an extra-morainic névé. Perhaps a certain distribution of precipitation might favor such

results. Over a snow-covered region of this kind there would be ideal conditions for loess-making. A slow creeping of the entire field might very well be supposed to take place in the direction of the general slope of the land.

It is not my desire to discuss these possibilities here. The object of this communication is merely to call attention to this new feature of the loess, and, if possible, thereby to secure more observations on its occurrence.

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THE PALÆONTOLOGICAL COLLECTIONS OF THE GEOLOGICAL DEPARTMENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY.[1]

THE geological department of the American Museum of Natural History completed in December, 1901, the publication of a catalogue of the types and figured specimens in its possession, by R. P. Whitfield, assisted by the author of the present note. This work has been under way for several years, and in its published form makes up a book of more than five hundred pages, forming Volume XI of the *Bulletin* of the Museum. This is one of the oldest departments of the museum, and its chief possession is the great James Hall collection, which was acquired in 1875, and which placed it at once in the front rank of American museums containing similar material. This collection will always be the standard reference series for all workers in North American Palæozoic palæontology, since it contains a very large proportion of the specimens described and figured by Professor Hall in the course of his work on the *Palæontology of New York* up to the time of the purchase of the collection by the American Museum. From time to time the department has received other collections, through exchange and other means, but, with the exception of the Holmes collection, they contained few types at the time of their acquisition. Most of the "figured specimens" in the collections of the department are those which were identified, re-described, illustrated, and published by Professor Hall in the *Palæontology of New York*, and therefore they have almost the dignity and value of types.

Of the specimens described and illustrated in the quarto volumes of the *Palæontology of New York*, the Museum possesses two-thirds of those in Volume I, covering the Cambrian and Lower Silurian systems; nearly eight-tenths of those in Volume

[1] Read before the Geological Society of America at Rochester, N. Y., January 2, 1902.

II, extending from the Medina to the Onondaga stages, inclusive; three-fourths of those in Volume III, which treats of the Lower Helderberg and Oriskany groups; more than one-third of those in Volume IV, which describes the Brachiopoda of the Devonian system from the Upper Helderberg to the Chemung; about 30 per cent. of the specimens illustrated in Volume V, Part I, which is devoted to the Lamellibranchiata of the Upper Helderberg (or Corniferous), Hamilton, and Chemung groups; and a nearly equal proportion of the Cephalopoda and Gastropoda illustrated in Volume V, Part II. The collection, however, contains only about seventy-four of the specimens of Bryozoa given in Volume VI, and about seventy of the Crustacea illustrated in Volume VII of the *Palæontology of New York*. Much of the material for Volume VIII, on the Brachiopoda, was prepared for publication prior to 1876, hence a large proportion of the specimens used for illustrations are to be found in the American Museum, especially of those used for the plates bearing the name of R. P. Whitfield.

Most of the species in the volumes above mentioned were first published in the *Regents' Reports on the Condition of the State Cabinet* (or State Museum, as it is now called), but material from other states than New York was also used in these reports, and the American Museum has the fossils from the Wisconsin-Minnesota Cambrian beds described and figured in the *Sixteenth Report;* the Niagara material from Waldron, Ind., published in the *Twenty-eighth Report;* and the graptolites and the Wisconsin Niagara species given in the *Twentieth Report*. The Trenton fossils from Wisconsin described in the *Report of Progress of the Geological Survey of Wisconsin for 1861* are here, and the original descriptions have been republished with illustrations and notes by R. P. Whitfield in the *Memoirs of the American Museum of Natural History*, Volume I, Part II. The Museum has all the Warsaw fossils from Spergen Hill, Ind., originally published without figures by Hall in the *Transactions of the Albany Institute*, Volume IV, and republished by Whitfield with figures in *Bulletin Am. Mus. Nat. Hist.*, Vol. I. The collection also includes the

type fossils from the Clinton beds at Arisaig, Nova Scotia, described by Hall in Volume V of the *Canadian Naturalist and Geologist;* many of the Devonian and higher forms described by the same author in the *Geology of Iowa* and the *Supplement to the Iowa Report*, the latter being republished with figures by Whitfield in *Mem. Am. Mus. Nat. Hist.*, Volume I, Part I; several type specimens of the Dictyospongidæ, some of which have been described by Whitfield in the *Bulletin of the Am. Mus. Nat. Hist.*, Volume I, and others by Hall and Clarke in a *Memoir on the Palæozoic Reticulate Sponges;* Hall and Meek's types from the Cretaceous of the Bad Lands of Dakota, Nebraska, and Wyoming, described in the *Memoirs of the American Academy of Science and Arts*, Volume V; the fruits and seeds from the Eocene beds at Brandon, Vt., described by Lesquereux and published in Hitchcock's *Geology of Vermont;* and some of the Cephalopoda, Gastropoda, and Lamellibranchiata described by Whitfield in his U. S. Geological Survey monographs on the *Cretaceous and Tertiary Fossils of New Jersey*. The museum also has the Holmes collection, which includes more than two hundred of the specimens described and figured by Tuomey and Holmes's *Pleiocene Fossils of South Carolina* and in Francis S. Holmes's work on the *Post-Pleiocene Fossils of South Carolina*. The fossils described in the various bulletins and memoirs of the American Museum of Natural History are here as a matter of course. In addition to the republication of certain of Hall's types already mentioned, there have been described and illustrated in the *Bulletin* a large series of fossils of Chazy and Birdseye age from Fort Cassin, Vt.; Beekmantown, N. Y., and other localities on Lake Champlain, and many Cretaceous forms from Beirût, Syria, and from Jamaica, W. I.

The catalogue has been issued in four parts. Part I, including the Cambrian and Lower Silurian forms, was issued in July, 1898; Part II, containing the Upper Silurian specimens, was issued in October, 1899; Part III, comprising the Devonian forms, came out in October, 1900; Part IV, containing the specimens from the Lower Carboniferous to the Quaternary inclusive.

and the index, preface, and table of contents of the whole volume, bears date of December 27, 1901.

This work has determined that there are in this department of the museum at least 6,166 type specimens, representing 2,222 species and 71 varieties; and 2,179 figured specimens, not types, representing 499 species and 119 varieties. Three-fourths of this material has come from the Palæozoic systems above the Cambrian.

EDMUND O. HOVEY.

PALÆONTOLOGICAL NOTES.

Lysorophus tricarinatus.—In 1877 Cope described from the Permian bone bed of eastern Illinois, three small vertebræ which he referred to a new genus and species, *Lysorophus tricarinatus.* The specimens were later redescribed and figured by the author in the JOURNAL OF GEOLOGY, Vol. VIII, p. 714, Plate II, Figs. 12*a*, 12*b*, 12*c*. This genus has not previously been recognized from any other locality, but in looking over a portion of the University of Chicago collection of Permian vertebrates from the Texas region I find the genus represented by some very interesting specimens. In a very restricted locality I found (the author collected the specimens here described) several series of vertebræ with attached ribs, which were peculiar in that the animal was evidently closely coiled when fossilization took place. This is such a persistent feature that some trace of it is noticeable in even the shortest series of vertebræ. It is difficult to explain this feature; the late Dr. Baur, before the specimens were identified, suggested that they might be embryos, but this seems rather improbable from the persistence with which the vertebræ cling together, and the very perfect degree of ossification. Another peculiarity is that the ribs are almost always attached but are crushed down and to the rear and are closely folded upon the vertebræ. In Fig. 1, Plate I, is shown one of the series of vertebræ with attached ribs, the curvature is not shown as it lies in the plane, perpendicular to the paper, but it is very noticeable in the specimen.

In the type specimens only the centra were known, and the deep pits on the sides, with the sharp intervening keels were made the determining characters of the genus. In the specimens from Texas, the neural arches are still in position, but the line of suture is very distinct; in the few vertebræ which have lost the neural arch, the characteristic angulation of the articular face of the centrum for the base of the neural arch, and the deep pit

in the floor of the neural canal between the arches are very distinct. A further point of interest lies in the fact that the two sides of the neural arch are united at the top by suture only, this remains distinct through life, as it is clearly seen in the largest and best ossified specimens. The ribs have but one head, and there seems to be no articular face preserved, indeed, in many of the specimens it looks as if the rib had been anchylosed to the end of the transverse process and broken off when the ribs were bent down to their present position. In some of the vertebræ the end of the transverse process shows the articular face for the rib. The top of the neural arches was expanded so that it forms a broad, low arch which is longer than the centrum and overlies rather widely the anterior zygapophyses of the succeeding vertebræ, Fig. 2, Plate I, shows one of the larger vertebræ twice natural size.

MEASUREMENTS.

Height from bottom of centrum to top of neural arch,	7^{mm}
Greatest length of centrum,	5
Greatest length of the upper portion of the neural arch,	7

With the specimens of the vertebral column of *Lysorophus* was found a fragment of a small skull consisting of the anterior portion of the snout as far back as the middle of the orbit, and the anterior portion of the attached lower jaw. There is no reason to connect this specimen with the others, except that it occurs in the same restricted locality, a few square yards, and that no other bones were found, even after a careful search. So far as the specimen goes, it corresponds almost exactly with the description and measurements of *Isodectes* (*Pariotichus*) *megalops* Cope. From the character of the deposits it seems very probable that the skull belongs with the other specimens, and that we may have the skull of *Lysorophns*, if so, however, the genus *Isodectes* must be removed from the *Pariotichidae* as the vertebral column of that family has nothing in common with that of *Lysorophus*. No trace of the limb bones were found, and this with the coiled and firmly articulated vertebral column with its strong ribs has a very snake-like character, and it seems probable that the animal was very long-bodied and slender.

Pelycosauria.—Among the specimens in the Chicago collection is a single sacral vertebra which presents some very interesting points. It is the anterior one of the sacral series, and to one side is attached the sacral ribs in the natural position. The rib is united by a close articulation to the centrum, and the distal face is much expanded and turned somewhat to the rear. The lower edge of the centrum is preserved, and shows that it had the same peculiar oblique form characteristic of the cervical and sacral series of the Texas *Pelycosauria*. But the main interest centers in the neural arch as shown in Figs. 3 and 4, Plate I.

The base of the neural arch is perorated on each side by a large foramen. Between the posterior zygapophyses a stout ridge extends up the middle of the spine, and there is a rudimentary articular process at the base of the ridge. The upper half of the posterior face of the centrum is broad and flattened, and evidently served to form a very strong articulation with the second sacral. This seems to indicate the beginning of a sacrum, or it may be pathological. Unfortunately the specimen was isolated when found, so that the relation to the succeeding vertebræ cannot be exactly determined.

The pelvic and thoracic girdles of the American *Pelycosauria* have as yet been almost unknown. Cope published a figure of the scapula and coracoid of *Dimetrodon* and the author published with Dr. Baur a figure of a second specimen of the same; both of these specimens were somewhat incomplete. In 1886 Cope published a figure of the interclavicle of a *Pelycosaurian*. A peculiarly perfect specimen in the Chicago collection makes it possible to restore the thoracic girdle with much certainty. There are preserved the clavicles of both sides, the interclavicle, the scapula with attached coracoid and epicoracoid bones of one side and less perfectly the same bones of the other side. One of the clavicles lies upon the outer, under, side of the anterior expanded end of the interclavicle and the other lies upon the scapula.

The interclavicle is somewhat broken and the outer edges of the expanded portion are broken away in places, but the main

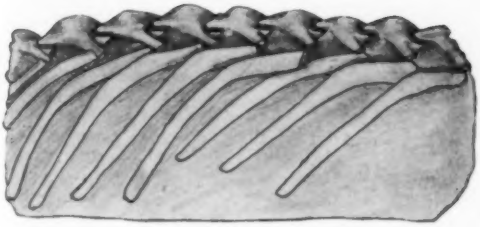

Fig. 1.

Fig. 2.

Fig. 3.

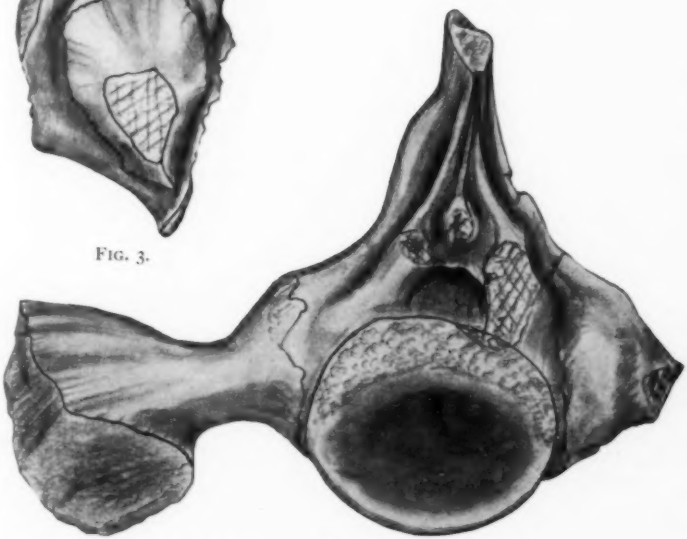

Fig. 4.

portion is preserved and it is evident that it does not differ materially from the form figured by Cope in 1886. The expanded end is very thin and the edges ended in digitate expansions. The posterior elongation is thicker in the middle, but thins out at the edges.

The clavicles are peculiar bones, widely expanded at the inner extremity where they overlap the interclavicle and with almost rectangular anterior inner corners. Toward the outer extremities they come almost to a point and in life overlay the middle portion of the scapula. The whole bone is slightly curved to conform to the girdle and is thin and plate-like at the inner portion and stouter and more rod-like distally. The prominence near the middle of the distal side is rugose and evidently served for ligamentous attachment.

The scapula and epicoracoid of one side are preserved almost complete and in the natural curvature; the coracoid is equally well preserved, but, as is common, separated from the others. (In the figure of the thoracic girdle the scapulæ appear slightly too long as in the representation on the flat the curvature does not appear.) The bones are quite similar to those figured in the papers cited, but the epicoracoidal edge is more rounded; the whole epicoracoid is very thin. The suture between the epicoracoid and scapula runs through the middle of the articular face for the humerus and then fades out into an almost complete anchylosis of the bones near the anterior edge. Fig. 6, Plate II, shows the scapula and epicoracoid without the coracoid in profile, giving a good idea of the curvature of the shoulder girdle.

The pelvis of the *Pelycosauria* has not previously been made out. Cope described what he considered to be the pelvis of *Dimetrodon*, but later discoveries showed it to be the pelvis of the amphibian *Eryops*. The same specimen which furnished the thoracic girdle described above affords an almost perfect pelvis. The bones are preserved in the same refractory iron-sand cement as the rest of the specimen and the slender edges of the bones have suffered accordingly, but the main portion of the bones

remain and enough of the edges to make the restoration here given fairly accurate. The three bones meet in the center of a wide and rather shallow cotyloid cavity with a very prominent inferior-posterior lip projecting from the ischial portion. The ilium is rather blunt anteriorly and tapers posteriorly, the inferior edge is thicker and rather rod-like and the upper portion is thinner and more plate-like. Attached by the iron cement to the inner side of the ilium are the distal ends of three sacral ribs, the anterior shows the same characters as figured in the solitary sacral vertebra described above. The anterior upper edge of the pelvis, formed by the adjacent portions of the ilium and pubis is rather rugose. The pubis is rather elongate, the upper edge is thicker and the lower thinner and plate-like. The ischium has a very thick acetabular portion which forms a prominent lip as described; the rest of the bone is very thin and is rather rounded in outline. Closely cemented to the inner face of the ischium figured is the lower portion of the same bone of the opposite side. This ischium differs quite markedly from another in the same collection which is much more elongate and slender.

It is peculiarly unfortunate that a specimen which is so completely preserved should be preserved in a cement so hard that it is only by the sacrifice of the superficial layer of the bone that it can be removed. Any attempt to remove the cement is an almost hopeless task as it strikes sparks from the chisel; however, enough has been made out to show that it contains a nearly perfect half of the skull, the majority of the vertebral column, most of the limb bones, and a nearly perfect anterior foot, all of which the author hopes to describe and figure at an early date.

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Milwaukee.

EXPLANATION OF PLATES I AND II.

FIG. 1.—Series of vertebræ from the middle portion of the column of *Lysorophus tricarinatus*. One-half natural size.

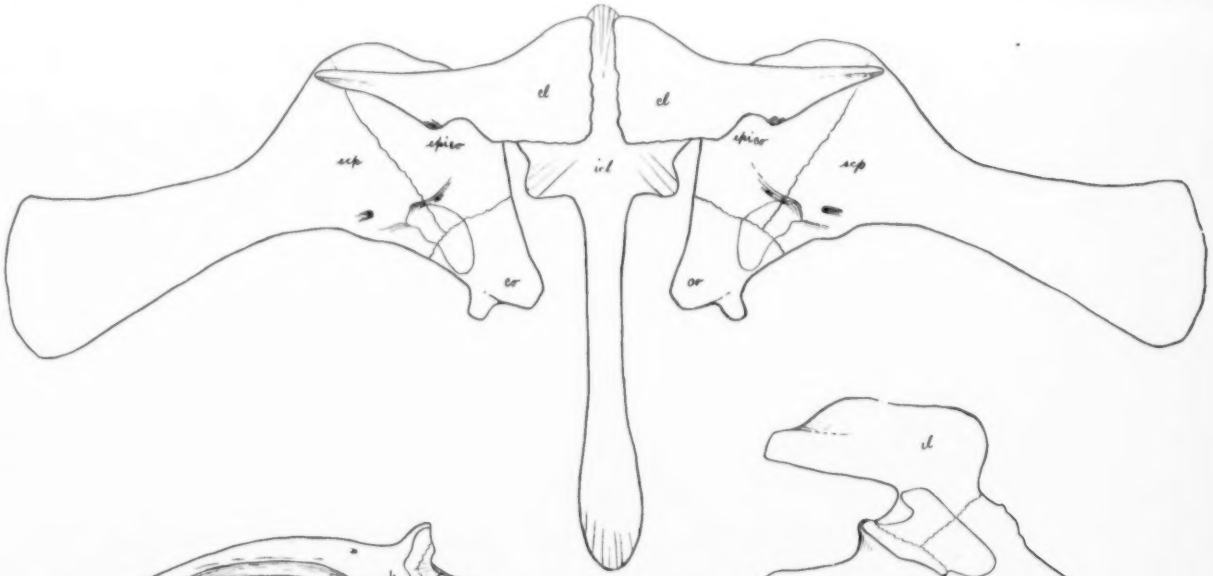


FIG. 5.

FIG. 6.

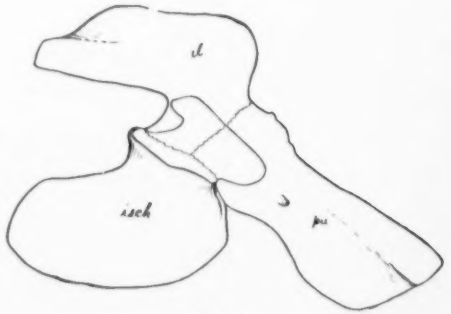


FIG. 7.

FIG. 2.—Vertebra from the middle portion of the column of *Lysorophus*. Twice natural size.

FIG. 3.—Lateral view of the first sacral vertebra of an undetermined Pelycosaurian. Natural size. The distal end of the sacral rib is detached.

FIG. 4.—Posterior view of the same vertebra with the distal end of the rib attached. Natural size.

FIG. 5.—Restoration of the shoulder girdle of a *Pelycosaurian, Embolophorous* (?). One-fourth natural size.

FIG. 6.—Profile view of the scapula and epicorcoid shown in Fig. 5. The coracoid is not shown. One-fourth natural size.

FIG. 7.—Restoration of the pelvis of the same animal as shown in Fig. 5. One-fourth natural size.

THE SUNBURY SHALE OF OHIO.[1]

CONTENTS.

Introduction.
Historical review.
Distribution.
  Central Ohio.
    Rattlesnake Creek near Sunbury.
    Rocky Fork.
  Southern Ohio.
    Benner's Hill.
    Stony Creek.
    Waverly.
    Buena Vista.
    Vanceburg.
  Northern Ohio.
    Berea.
    Bedford.
    Chagrin Falls.
    Warren.
    Orangeville.
Conclusion.
Note.

INTRODUCTION.

OVERLYING the well-known Berea grit of Ohio is a black shale of somewhat variable though never very great thickness. It forms, however, a marked horizon in the Waverly series, and is very presistent in outcrop, extending from the Ohio river to northern Ohio, thence east nearly to the Pennsylvania line, and perhaps enters the state. On the south it crosses into Kentucky; but its extent in that state is not known. The older names, the Waverly black slate of Andrews and the Berea shale of Meek, when first applied to this shale were preoccupied, being in use for other geological divisions.

Professor Hicks at a later date gave the name "Sunbury shale" to a rather meager exposure on the bank of Rattlesnake Creek, about two miles east of the village of Sunbury, in the eastern part of Delaware county, Ohio, which is the first distinctive geographic name applied to this shale and therefore the one which, it appears to the writer, ought to be accepted for this formation. Recent examination of outcrops of this shale at different localities across the state has acquainted the writer with its characteristics, and furnished him with some facts which are perhaps worthy of record.

[1] Published by permission of Professor Edward Orton, Jr., state geologist of Ohio.

HISTORICAL REVIEW.

There have been different opinions regarding the age of the Sunbury shale, and mistakes in regard to its correlation between the northern and southern parts of the state, so that it is thought advisable to give a brief review of its literature.

The shale was first recognized and named by Professor E. B. Andrews, in 1870, from outcrops in the Ohio valley in Adams and Scioto counties. He stated:

> There is a remarkable exception to the general character of the Waverly group, in a stratum of highly bituminous black slate, which is found about 137 feet above the base. It is sixteen feet thick, and remarkably persistent in the Waverly, and is said by my associates to be found in the northern part of the state. . . . . It contains the same mollusca, genera and species, as the black slate [Huron shale] viz., Lingula sub-spatulata M. & W., and Discina capax? White. It also contains similar scales of small ganoid fishes. Besides these fishes there are remains of larger fishes.[1]

To this shale Professor Andrews gave the name of Waverly black slate, and reported that it "is evidently a very widespread stratum. It is not only found extending through the Waverly formation to the north, but it evidently accompanies the Waverly rocks in their dip under the Coal-measures."[2]

In 1873, in describing the geology of Cuyahoga county, Dr. Newberry mentioned that the lower part of the Cuyahoga shale immediately overlying the Berea grit at Berea and Chagrin Falls contained "myriads of *Lingula melie* and *Discina Newberryi*. With these are a few scales of *Palæoniscus*, a Carboniferous ganoid and teeth of *Cladodus*, a Carboniferous shark."[3]

Under the description of Summit county occurs a similar statement, where it is reported that "at the base of the formation [Cuyahoga shale], however, immediately over the Berea grit, the Cuyahoga shale is sometimes crowded with millions of *Lingula melie* and *Discina Newberryi*."[4]

In 1874, Dr. Newberry apparently correlated the Waverly

[1] *Geol. Surv. Ohio*, "Rept. of Progress in the Second District" [in 1869], 1870, p. 65.

[2] *Ibid.*, p. 66.

[3] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, pp. 185, 186.

[4] *Ibid.*, p. 212.

black shale of southern Ohio with the Cleveland shale of northern Ohio. It will be remembered that the Bedford shale underlies the Berea grit in northern Ohio, and next lower is the Cleveland shale, which Dr. Newberry considered as the lowest division of the Waverly group. Dr. Newberry wrote that from northern Ohio "south to the Ohio river, the Cleveland shale is met with in various sections of the Waverly, but diminishing in thickness in this direction."[1]

And in reference to Professor Andrews' report of 1870 is the statement that he "mentions in his report that two fossils, *Lingula subspatulata* and *Discina capax*, are common to the Huron shale and the 'Waverly black slate' (Cleveland shale). This is probably an error of identification as, so far as yet known, the fossils of the two formations are quite distinct."[2]

The above interpretation of Dr. Newberry's correlation is supported by Dr. Orton's account of the Waverly group of Pike county, in which he states that:

> Immediately above the Waverly quarries comes in a very interesting formation, to which attention has been repeatedly called in the previous reports of the survey. The formation in question has been designated by the chief geologist the "*Cleveland shale*," and by Professor Andrews the "*Waverly black slate*." It consists of a black shale more highly charged with bituminous matter than the great black slate below it, the proportion sometimes rising as high as 24 per cent. Unlike the slate below it, viz., the Huron, it is often highly fossiliferous. Two species of brachiopods are especially abundant in it, viz., *Discina capax* and *Lingula sub-spatulata*. The remains of fishes are also of frequent occurrence. Its thickness, as measured in the Scioto valley, varies from seventeen and a half feet to twenty-seven feet.[3]

Dr. Orton also describes this black shale in his account of the geology of Ross county, and correctly reported the names of the two fossils which are abundant in the shale. His account is as follows:

> The greatest thickness yet observed in this formation is found in Franklin township, near the mouth of Stony Creek, where it measures not less than twenty-seven feet. It is charged at this point with its characteristic

[1] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. I, "Geology," 1874, p. 93.

[2] *Ibid.*, p. 96. [3] *Ibid.*, p. 624.

fossils, *Lingula melie* and *Discina Newberryi*, and the remains of fishes, often in an excellent state of preservation, can hardly be called rare. The teeth and the plates are the parts generally shown.[1]

Professor N. H. Winchell, who wrote the geological description for several counties in northern Ohio, identified numerous outcrops of the Berea grit in northern central Ohio in Crawford, Morrow, and Delaware counties,[2] but probably did not find outcrops of the superjacent black shale, as it is not mentioned. There was no doubt in his mind regarding the identification of the Berea grit, as may be seen by the statement at the close of his account of the sections and the distribution of the formation in Delaware county, where he says:

> In general, the Berea grit in Delaware county is a very excellent stone for all purposes of building, and is very extensively quarried at Sunbury. It appears however, to be of a finer grain than in the northern part of the state, and the massive beds that characterize it in Lorain county are entirely wanting.[3]

Professor Winchell had studied the Berea grit at typical localities in the northern part of the state, and he correctly identified it as far south as near the southern line of Delaware county, in Harlem township. Had his correlation been accepted by later observers, the confusion which existed for several years regarding the correlation of the Waverly formations of northern and southern Ohio would have been obviated.

In 1875 Meek, in giving the horizon of *Discina* (*Orbiculoidea*) *Newberryi* Hall, stated that certain specimens came "from the Berea shale, a member of the Waverly group of the Lower Carboniferous,"[4] which is apparently the first usage of this name in a stratigraphical sense, although it does not clearly appear that Meek intended to recognize the shale as a stratigraphic unit.

In 1878, Dr. Orton published his *Report on the Geology of Franklin County*, in which it was stated that in the county the following divisions of the Waverly series arranged in ascending order are shown, viz., Waverly shales, ten to twenty feet; Wav-

[1] *Ibid.*, pp. 648, 649. [2] *Ibid.*, pp. 240, 259, 280. [3] *Ibid.*, p. 282.

[4] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. II, "Palæontology." 1875, p. 278; also see statements in explanation of Plate XIV.

erly quarry system, sixty feet; and Cleveland shales fifteen feet.[1]

There was also reported a band of red or chocolate colored shale from fifteen to twenty feet in thickness at Taylor's Station, Jefferson township, and at several points in the eastern bank of Big Walnut Creek in Mifflin and Blendon townships,[2] which Dr. Orton considered the uppermost part of the Huron shale. This red shale, however, and the overlying Waverly shales represent the Bedford shale of Dr. Newberry's classification in northern Ohio. The Waverly quarry system is the Berea grit, although Dr. Orton in referring to Professor N. H. Winchell's report on Delaware county, in which outcrops at Sunbury and other localities in that county are correlated with the Berea grit, stated that "The Sunbury stone is erroneously referred in Vol. I [Vol. II], p. 282, to a higher division of the Waverly, viz., the Berea grit."[3] Finally, Dr. Orton stated, concerning the upper division of the Waverly as reported for Franklin county, that:

> The Cleveland shale of Dr. Newberry, the Waverly black shale of Professor Andrews, ... is known at but a single locality in the county, viz., at Ealy's Mills, in Jefferson township, on the banks of Rocky Fork. From ten to fifteen feet of this formation are here shown within the compass of an acre. The stone immediately underlying the black shale is quarried for local use, so that the line of junction is very distinctly seen at several points. The black shale lies upon the flat surface of the sandstone without the interposition of any other material whatever. A geological boundary cannot be more distinct than this. . . . . The surfaces of many slabs are thickly covered with the teeth and plates, and bones of the sharks and ganoids of this early day. Two brachiopods also, *Lingula melie* Hall, and *Discina Newberryi* Hall, are abundant here, sometimes wholly covering the surface of the beds. The anomalous but very interesting fossils termed *conodonts* are found in great numbers and in exquisite preservation in the shales of this locality.[4]

It is now known that the Cleveland shale is older than the Waverly black shale of Professor Andrews, and that the black shale on Rocky Fork is the continuation of the Berea shale of

[1] *Rept. Geol. Surv. Ohio*, Vol. III, Pt. I, "Geology," p. 639.

[2] *Ibid.*, p. 638. [3] *Ibid.*, p. 642. [4] *Ibid.*, p. 642.

Meek, which is represented in the Ohio valley by the Waverly black shale of Andrews.

In July, 1878, Professor L. E. Hicks, of Denison University, published "the discovery that an unmistakable outcrop of Cleveland shale exists two miles east of Sunbury in Delaware county, southern [central] Ohio, on the land of Horace Whitney. It lies *above* the calcareous sandrock of the Sunbury quarries, which Professor N. H. Winchell, a special assistant on the Ohio Geological Survey, identified as *Berea grit*. My discovery *demonstrates* the incorrectness of that identification, and raises strong presumption, amounting almost to a certainty, that he was equally wrong in respect to his Berea grit in Morrow and Crawford counties."[1]

Professor Hicks was mistaken in this identification, and his conclusion regarding Professor Winchell's work was likewise erroneous; for the black shale which Hicks called the Cleveland is the Berea shale of Meek resting on top of the Berea sandstone, and therefore Professor Winchell's identification was correct.

In the September number of the same periodical, Professor Hicks named and described the divisions of "the Waverly group in central Ohio," or, "the strata lying between the Huron shales (Devonian) and the base of the Coal-measures," selecting "names derived from localities in Licking and Delaware counties."[2] In ascending order these names are (1) "Sunbury calciferous sandrock," 90 to 100 feet thick, which is the Berea grit; (2) "Sunbury black slate," from 10 to 15 feet in thickness, which is the Berea shale; (3) "Raccoon shales," 300 feet thick, a good exposure of which occurs on Moot's Run, a tributary of Raccoon Creek, four and one-half miles west of Granville, which are the equivalent of at least the lower and middle portions of the Cuyahoga shales of northern Ohio; (4) "Black Hand conglomerate and Granville beds," 85 to 90 feet thick; and (5) "Licking shales," from 100 to 150 feet thick.[3] In addition to

[1] *Am. Jour. Sci. and Arts*, 3d ser., Vol. XVI, p. 71.

[2] *Ibid.*, p. 216. [3] *Ibid.*, p. 216.

the localities suggested by the names of these last two divisions the quarry beds of No. 4 are excellently shown in the Vogelmeier and Haven's quarries south of Newark and the Licking shales in "the gorge" to the southeast of Haven's quarry and Newark. These last two divisions of southern central Ohio were termed by Dr. Orton the Logan group.

In this paper Professor Hicks states:

> The Cleveland shale has been assumed by the Ohio geologists to be equivalent to the Waverly black slate, which is undoubtedly the same as that at Sunbury. At the time I discovered the outcrop at Sunbury I supposed there was no doubt of the correctness of this assumption. Now, however, Dr. Newberry asserts positively that there is *no evidence*, that they are identical.[1]

This is the first published statement, as far as the writer is informed, calling in question the correlation of the Waverly black slate of southern Ohio with the Cleveland shale of the northern part of the state; so it would appear that, as early as the summer of 1878, Dr. Newberry was aware of the mistake in his earlier correlation of these shales. Furthermore, Professor Hicks states that if Professor Winchell was correct in calling the Sunbury quarry stone the Berea grit, then "the chocolate shale described by President Orton as constituting the upper part of the Huron may be of the same age as the Bedford shales, as they were supposed to be by Dr. Newberry.[2] This appears to be the first published tentative identification of the Bedford shale in central Ohio, for in Dr. Newberry's account of the Carboniferous system, published in 1874, he stated:

> South of the Western Reserve the Bedford shales are scarcely distinguishable as in the central and southern portions of the state they assume the prevailing character of the Waverly group, and blend with the other portions of the series.[3]

The writer is not aware of any published opinion of Dr. Newberry's regarding the correlation of these red shales of Franklin county with the Bedford shale of northern Ohio.

In August of the following year, Dr. Orton published a

[1] *Ibid.*, p. 221. [2] *Ibid.*, p. 221.

[3] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. I, p. 92.

"Note on the Lower Waverly Strata of Ohio," in which the black shale of southern Ohio is for the first time correctly correlated with the black shale overlying the Berea grit in northern Ohio. Dr. Orton said:

> The identify of the Waverly black shale of southern Ohio and the Cleveland shale of northern Ohio, which was suggested as probable ten years since by Dr. Newberry, and which has since been adopted by most of those who have written on the geology of the Waverly group in Ohio, proves to be an error. . . . . The Waverly black shale finds its place directly above the Berea grit to the northward. The stratum has been distinctly described in the reports on the northern counties, but it has not been distinctly named. It has been treated of as the dark, fossiliferous shale at the base of the Cuyahoga shale. No better name could be found for it than Berea shale — for it makes the roof of the Berea quarries, just as it does of the lower Waverly quarries of Pike county.[1]

Dr. Orton made no reference to the paper of Professor Hicks of the preceding year in which he gave the name of Sunbury black slate to this formation in central Ohio; nor to Winchell's earlier correct identification of the Berea grit in central Ohio.

Dr. Orton gave a table correlating the Waverly formations of northern with those of southern Ohio. In this table the 75 feet of Bedford shale in the north is given as synchronous with the 90 feet of Waverly shale in the south; the 60 feet of Berea grit is equivalent to the 60 feet of the Waverly quarries and overlying blue shale; and the 10 feet of Berea shale is correlated with the 15 feet of Waverly black shale; while the 150 to 250 feet of Cuyahoga shale is represented by 300 to 400 feet of shale and sandstone in southern Ohio.[2]

In 1881, Dr. Orton read a paper before the American Association for the Advancement of Science, at Cincinnati, on "The Berea Grit of Ohio," in which he emphasized the fact that there is no serious difficulty in tracing the formation across the state, and again reviewed the correlation of the Waverly formations between northern and southern Ohio. In reviewing the earlier correlation he said:

> It will be observed that a comparatively thin bed of black shale occurs

[1] *Am. Jour. Sci.*, 3d ser., 1879, Vol. XVIII, p. 138. [2] *Ibid.*, p. 139.

in northern Ohio, overlain and underlain by blue shales, viz., the Cleveland shale, overlain by the Bedford and underlain by the Erie shale. A bed of black shale with similar boundaries has been noted in southern Ohio, viz., the Waverly black shale of Andrews. This latter stratum was assumed to be the true equivalent and extension of the Cleveland shale, and its fossils soon came to be credited to the latter. This identification placed the Berea grit of the north and the Buena Vista quarries of the Ohio valley on the same horizon.[1]

Dr. Orton stated that Professor N. H. Winchell first traced the Berea grit to central Ohio, as has already been shown in this paper; but he further said that "the Waverly quarry stone had been followed from the southward" to this part of the state, and "to abandon the preconceived error . . . . cost time and trouble." This, as far as the writer is aware, is the nearest published reference made by Dr. Orton to his classification of the Waverly rocks in the Franklin county report which has already been reviewed. Dr. Orton also reported that:

> The Waverly black shale of southern Ohio proves to be the black base of the Cuyahoga shale of northern Ohio, instead of the Cleveland shale, to which it was at first referred. The Waverly blue shale of southern Ohio is the Bedford shale of the north, like it also carrying enough peroxide of iron to redden it in many instances.[2]

In 1882, in discussing the source of the bituminous matter in the Devonian and Subcarboniferous black shales of Ohio, Dr. Orton wrote as follows:

> There are three strata of black shale in the Devonian and Subcarboniferous series of Ohio, viz., the Huron and the Cleveland shales of Newberry and the Waverly black shale of Andrews. The latter name I have followed Meek in replacing by the designation "Berea shale." It constitutes the base of the Cuyahoga shale of Newberry. . . . . The Berea shale, which directly overlies the Berea grit, ranges from 15 to 50 feet in thickness, and is separated from the great black shale [Ohio shale] by an interval of 100 to 150 feet, the interval being occupied by the Bedford shale and the Berea grit of Newberry. In northern Ohio the upper boundary of the Berea shale is not well defined. In central and southern Ohio it is sharp and distinct.[3]

In 1888, Dr. Orton described the Berea shale in his account

[1] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXX, 1882, p. 170. [2] *Ibid.*, p. 171.

[3] *Am. Jour. Sci.*, 3d ser., Vol. XXIV, p. 171.

of the "Geology of Ohio,"[1] but added nothing to what has already been cited, and this account was republished in 1893.[2]

Professor Cushing reported the Berea shale in northeastern Ohio, with a thickness of 40 feet overlying 35 feet of Berea grit, near the Pennsylvania line, and farther west in his section through Warren, Trumbull county, 55 feet of Berea shale.[3]

For some years Professor C. L. Herrick studied the Waverly series, and in his general conclusions introduced the term "Berea" or "Transition series," which included the rocks from the base of the Cleveland shale to either the bottom or top of a conglomerate in the upper part of the Waverly, which he called conglomerate I.[4] It is not clear whether this conglomerate was included in the Berea series or not, for on page 100 it is given in this series, but on page 105 it is given in the overlying Kinderhook division. One of the divisions of the Berea series he called the Berea shale, but included in it not only the black shale which Dr. Orton called the Berea, but also the greater part of the overlying Cuyahoga shale as defined by Dr. Orton. The upper 40 feet of shale in the Berea series underlying conglomerate No. 1 was called the Waverly shale.[5]

In a later paper, however, Professor Herrick was not inclined to extend the limits of the Berea shale beyond those of Dr. Orton, for he wrote as follows, under the heading "Berea Shale":

> This term is conveniently applied to the thin band of bituminous shale above the [Berea] grit and perhaps should not be extended (as the writer has done in a previous paper) to the gray and blue shales above. In southern Ohio it varies from fifteen to twenty feet in thickness and is little more than two feet thick at Chagrin Falls.[6]

Mr. W. F. Cooper, who continued the investigation of Professor Herrick on the Waverly series, used the term "Berea shale" in the sense in which it was first used by Professor Herrick; but made two divisions, viz., first, the lower Berea

[1] *Rep. Geol. Surv. Ohio*, Vol. VI, pp. 36, 37. [2] *Ibid.*, Vol. VII, p. 30.

[3] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXXVI, 1888, p. 214.

[4] *Bull. Denison Univ.*, Vol. IV, 1888.

[5] *Ibid.*, pp. 106, 107. [6] *Bull. Geol. Soc. Amer.*, Vol. II, Jan. 1891, p. 35.

shale, resting on the Berea grit, 180 feet (?) in thickness, capped by the upper Berea shale, 30 feet thick, which was described as "the most fossiliferous zone yet found in the Waverly of Central Ohio."[1] Later, however, Mr. Cooper used the term "Berea shale" in the sense in which it was used by Dr. Orton, for he wrote as follows:

> The Berea shale is immediately over the Berea sandstone. . . . . This horizon has also been called the Waverly black shale, by Andrews, varies in Ohio from 15 to 50 feet in thickness, throughout the line of outcrop, and is an exceedingly persistent and well defined horizon.[2]

In 1889, Dr. Newberry gave the thickness of the Waverly group in northeastern Ohio as about 500 feet, which he stated was composed of the following divisions:[3]

		Average thickness.
1.	Cuyahoga shale	230 feet
2.	Berea Shale	20
3.	Berea Grit	60
4.	Bedford Shale	75
5.	Cleveland Shale	50

He also referred to Professor Hicks' announcement of the discovery of the Cleveland shale in Delaware county, and stated that:

> I think he has found there the Berea shale, which lies immediately above the Berea grit. This latter shale is persistent southward, and is apparently the black shale, so rich in fish remains at Vanceburgh, Kentucky. I suspect the Cleveland shale does not pass south of the line of the Western Reserve.[4]

The above clearly shows that Dr. Newberry abandoned his early idea of the extension of the Cleveland shale across the state, and accepted the later correlation of the Berea shale of northern with the Waverly black shale of southern Ohio.

DISTRIBUTION.

CENTRAL OHIO.

Rattlesnake Creek near Sunbury.—In this account of the distribution of the Sunbury shale across the state we will begin with

[1] *Bull. Sci. Lab. Denison Univ.*, Vol. V, 1890, pp. 25, 26.

[2] *Geol. Surv. Michigan*, Vol. VII, Pt. II, 1900, p. 286.

[3] *Monographs U. S. Geol. Surv.*, Vol. XVI, "The Palæozoic Fishes of North America," p. 120.

[4] *Ibid.*, p. 129.

the locality in central Ohio, which has furnished its name, and then describe some of the more important outcrops from there south to northern Kentucky. Returning to Sunbury, its outcrop will then be traced to the north and east nearly to the Pennsylvania line.

The Sunbury shale was named by Professor Hicks in 1878, from exposures on Rattlesnake Creek, on the present farm of Amasa Whitney, about two miles east of Sunbury, Delaware county.[1] If an opportunity remained to select a place for the name of the formation, a much more conspicuous outcrop might be found, but as this has been regularly defined and published it is the writer's opinion that Sunbury shale should be accepted. Professor Hicks described the formation as "a black, bituminous shale containing shells of *Lingula* and *Discina* and spines, scales, and teeth of fishes. But one outcrop of it is known in Delaware county, and that was revealed only by a systematic search of a day and a half."[2] Some three and one-half feet of this shale is shown on the northern bank of Rattlesnake Creek a short distance north of the house of Amasa Whitney. As exposed it is black and argillaceous, rather rotten from weathering, greatly iron-stained between the layers with some lighter colored blotches, and contains iron pyrites. Below this outcrop, at irregular intervals, there are several exposures of the shale on the bank of the creek, and in a loose piece a specimen of a fairly large *Lingula* was found, which was the only fossil secured at this locality. The lower part of the shale, however, in which fossils are generally the most abundant, is not shown here, and the top of the Berea grit forms the bed of the creek a little below the house of Mr. W. P. Swallow. The upper layer of the Berea is greatly iron-stained, contains considerable iron pyrites, and has quite an irregular surface.

A little further down the stream is an outcrop on the southern bank where between two and three feet of thin bedded sand-

[1] *Am. Jour. Sci.*, 3d ser., Vol. XVI, pp. 216, 219, 220. Also see p. 71 for a further account of the locality.

[2] *Ibid.*, pp. 219, 220.

stone is shown. It is buff to bluish-gray in color, much of it quite iron stained, of fairly fine grain and somewhat friable. There is no question but that these outcrops just below the house of Mr. Swallow are in the very upper part of the Berea grit.

Rocky Fork.—Dr. Orton noted "an outcrop of black shale on the farm of Lorenzo Taylor, Esq., of Plain township," in the northeastern part of Franklin county, which he stated "may prove to belong to the Cleveland shale."[1] This outcrop has not been seen by the writer, but it is probably in the Sunbury shale, since it is situated about in the line of strike of this formation.

The best exposure of the Sunbury shale in central Ohio is on the banks of Rocky Fork, in Jefferson township, in the eastern part of Franklin county, 2.3 miles northeast of Gahanna. It is well shown on the banks of the creek, both below and above the highway bridge, on the David S. Stagg farm. The first high bank on the eastern side of the creek below the bridge gives a fine exposure of the middle and upper part of the Berea grit, capped by the lower half of the Sunbury shale. The section of this bank is as follows, and it is shown in Fig. 1.

ROCKY FORK SECTION.

No.		Thickness feet.	Total thickness feet.
6.	Soil and drift	7	37
5.	*Sunbury* black argillaceous shale, capping the Berea grit, the contact of which is finely shown on the vertical bank. About 8 inches above the base of the shale is a zone of fossils in which *Lingula melie* Hall was obtained	7	30
4.	Thick stratum of light gray sandstone forming the upper part of the *Berea grit*	6¾	23
3.	Parting of shaly sandstone to shales	....	....
2.	Zone of light gray to bluish-gray sandsone, somewhat irregularly bedded, and lenticular with some shale partings	12	16¼
1.	Shaly sandstone alternating with layers of shale, Berea grit to creek level.	4¼	4¼

The lower two or three feet of Sunbury shale capping the Berea grit is also shown on the western bank of the creek somewhat above the cliff just described; while at various places on

[1] *Geol. Surv. Ohio*, Vol. III, p. 643.

the bank and in the bed of the creek are magnificent examples of ripple marks in the fairly thin layers of Berea sandstone.

Just above the highway bridge is an old quarry in the upper part of the Berea grit, some of the layers of which are bluish in color. Capping the sandstone is the lower two feet or more of

FIG. 1.—Contact of Berea sandstone and Sunbury shale on Rocky Fork, two miles northeast of Gahanna. The thin bedded Sunbury shale is shown in the upper part of the cliff resting on a thick sandstone layer at the top of the Berea.

the black argillaceous Sunbury shale, and at this locality the clearly shown contact of the two formations may be closely examined. The black shale splits into thin layers, and one of these, a few inches above its base, contains abundant specimens of *Lingula melie* Hall and *Orbiculoidea Newberryi* (Hall), Herrick,[1] together with fragments of fish bones and teeth. Farther up the creek, on the same bank, 8 feet or more of the shale is shown.

On the eastern bank of the creek, not far above the highway

[1] Mr. Schuchert refers this species to Whitfield's genus of *Lingulodiscina* (*Bull. U. S. Geol. Surv.*, No. 87, p. 261).

bridge is a rock cliff, the lower 5½ feet of which, to the creek level, is the upper part of the Berea grit, while above is 7± feet of the Sunbury shale capped by drift and soil. The contact of the Sunbury shale and Berea grit is also nicely shown in this outcrop.

At this place was formerly a mill known as Ealy's, and this is the locality which was said by Dr. Orton to be the only one in Franklin county where the Cleveland shale of Dr. Newberry or the Waverly black shale of Professor Andrews was known. He stated that "from ten to fifteen feet of this formation are here shown within the compass of an acre."[1]

Some difficulty was experienced in obtaining the thickness of the Berea grit at this locality, and in a former paper the writer has given it as "about 40 feet."[2] South of the bridge, however, the first steep bank on the eastern side of the creek below the one which furnished the above section, apparently gives the base of the Berea grit, and unquestionably its top, so that we probably have the entire thickness of the formation given in this nearly vertical cliff. The Sunbury shale on the bank a little back of the edge of the cliff had not been noticed when the former paper appeared, although the apparent contact of the Berea grit and Bedford shale near the base of the bank was observed. The section of this bank is as follows:

No.		Thickness feet.	Total Thickness feet.
3.	Black argillaceous shale in thin layers; the base of the *Sunbury shale*	3	39½
2.	*Berea grit*, the upper part of which consists of fairly massive sandstones, the layers a foot or more in thickness, while the basal part is composed of thin bedded sandstones, and all through the formation shale partings occur at irregular intervals. Below these thin bedded sandstones are grayish shales, so that the entire formation is apparently shown between these two shales	33½	36½
1.	Grayish to bluish-gray, somewhat arenaceous shales to the creek level, which are considered as at the top of the *Bedford shale*.[3]	3	3

[1] *Geol. Surv. Ohio.* Vol. III, p. 642. [2] JOUR. GEOL., Vol. IX, 1901, p. 218.

[3] As is well known "Bedford oölitic limestone" has been used as the name of a Subcarboniferous formation in Indiana. The question has arisen whether Bedford

On the western bank of the creek, at the first cliff below the one just described, is a concretionary sandstone, the layer about 1 foot 8 inches in thickness, below which are grayish shales partly covered to the creek level. Above the concretionary sandstone are 7 feet 8 inches of shales, which are mainly argillaceous but become arenaceous at the top. These shales are succeeded by thin bedded sandstones, which are thicker above, showing at one place a conspicuous concretionary layer, and these sandstones are clearly in the Berea. When traced up the creek, however, the lower concretionary sandstone is apparently near the horizon regarded as the base of the Berea in the preceding section, and it is therefore thought to correspond more nearly with the base of the formation than the higher thin bedded sandstones. If this be accepted, however, as the base of the Berea, then there is 7⅔ feet of shale included in the lower part of the formation. In the short distance between these two cliffs a rapid change in lithologic character is indicated and the lower limit of the formation must therefore be regarded as a rather variable line.

Somewhat below this bank is a bend in the creek, where a steep cliff with a conspicuous tree near its edge is shown on the same side of the creek. At this locality the upper part of the Bedford shale is finely shown, as well as the transition into the Berea grit. The section is as follows:

should be retained as the name for the Indiana or Ohio formation, and both views have been pretty fully given in the JOURNAL OF GEOLOGY (see Vol. IX, April–May, pp. 215, 232–36, 267–72). Later the writer referred the matter to the committee on geologic names of the United States Geological Survey, which has been organized for the consideration of similar questions in geologic classification and nomenclature, and the following decision has been communicated by the director, Hon. Charles D. Walcott: "(1) That Bedford rock was used by Owen in 1862 in a *Report of Geological Reconnaissance of Indiana*, 1859–60, p. 137, but the usage is so indefinite as not to constitute a preëmption of the term for stratigraphic purposes. (2) Bedford shale is a term first employed by Newberry in *Ohio Geological Survey Report of Progress*, 1869, p. 29, and this usage should stand. Furthermore, it is understood here that Mr. Cumings has recently proposed to drop the name of Bedford limestone of Indiana, and substitute for it Salem limestone."

No.		Thickness feet.	Total thickness feet.
6.	Soil and drift	6	56½
5.	Grayish sandstone layers, about 1 foot thick, but with some shaly partings. *Berea grit*	13	50½
4.	Arenaceous shales	4	37½
3.	Argillaceous shales	6½	33½
2.	A concretionary layer of sandstone, which is thought to represent the base of the *Berea grit*	1±	27
1.	Argillaceous shales to the creek level; in the lower part are reddish-gray spots which give them a slightly mottled appearance, *Bedford shale*[1]	26	26

In the above section the concretionary sandstone — No. 2 — is regarded as marking the base of the Berea grit instead of the higher sandstones of No. 5, because No. 2 is thought to represent the concretionary sandstone noted on the bank farther up the creek, which was determined by level to correspond approximately with the base of the sandstones on the other side of the creek, where the entire formation is shown.

In the deeply drift-covered eastern part of Franklin county, which is also true of Fairfield county on the east and Pickaway county to the south, there are but few outcrops of the Sunbury shale. Dr. Orton noted its occurrence at one locality in Fairfield county, and his statement was that "it undoubtedly exists in Pickaway and Fairfield counties, though its presence has not been determined in either, except at a point just beyond the Franklin county line, to the south of Canal Winchester."[2]

SOUTHERN OHIO.

Benner's Hill. — In southern Ohio, in Ross, Pike, Scioto, and Adams counties, are numerous outcrops of the Sunbury shale, and its distribution may be readily traced across that portion of the state. In this paper only a few of these outcrops will be described, and they have been selected at some distance from each other in order to fairly represent the character of the formation across the southern part of the state.

[1] An earlier interpretation of this section was given in the JOURNAL OF GEOLOGY, Vol. IX, p. 217.

[2] *Geol. Surv. Ohio*, Vol. III, p. 643.

One of the most interesting sections of the Devonian and Subcarboniferous formations of southern Ohio is that of Benner's Hill, about two miles northwest of Bainbridge, in the southwestern part of Ross county. The section begins on the eastern bank of Buckskin Creek, a short distance below the railroad bridge and house of Mr. George Walley, and follows the steep part of the hill to the bare spot of shale known as Bald Knob, and then runs through the woods to the Walley sandstone quarry and top of the hill.

BENNER'S HILL SECTION.

No.		Thickness feet.	Total thickness feet.
7.	Covered to the highway directly east of the quarry, which crosses about the highest part of that portion of the hill. Loose by the roadside is brownish-red shale, which is apparently from near that horizon. The greater part of this covered slope belongs in the *Cuyahoga shale* - - - - - - - -	36	490
6.	Black fissile bituminous shale vertical wall of 9 feet on top of the quarry sandstone. *Sunbury shale*, formerly known as the Waverly black slate. The contact between the black shale and the subjacent Berea sandstone is beautifully shown on the vertical wall of the George Walley quarry. The contact is sharp and it makes a conspicuous line - - - - - -	9	454
5.	The upper 7 feet is a massive sandstone layer, which in places does not split into layers. The upper 18 feet of the formation is composed of very massive light gray, generally rather coarse-grained sandstone, with few bedding planes. Below is 13 feet composed of sandstones, the layers of which vary in thickness from 1 to 2½ feet, and alternate with shales. The color varies from bluish to buff and numerous layers of the sandstones in the lower part of the quarry show excellent examples of ripple marks. At the base, sandstones 6 inches or more in thickness alternate with shales; but this portion is partly covered, and a clear line of contact between the sandstones and the underlying Bedford shale is not shown. These sandstones represent the *Berea grit*, and were formerly called the Waverly quarry system - - - - - - - - - - - - - - -	33	445
4.	The interval of the *Bedford shale* is mostly covered; but at the base, near the line of springs, are brownish to buff arenaceous shales. The barometer gave 63 feet for the interval, which is perhaps greater than the actual thickness, since Dr. Orton gave it as 50 feet.[1] This formation was formerly known as the Waverly shales - - - - - - - - - - - -	63	412

[1] *Geol. Surv. Ohio*, Vol. II, p. 645.

3. Probable top of the Ohio shale as indicated by the line of springs, but the upper 7 feet is covered. From the bare summit of Bald Knob to base of shales, 325 feet, nearly all of which is shown by following the run on the lower part of the hill and higher, on its steep western face. The rocks are thin black fissile shales, weathering to a somewhat lighter color, and some of the pieces contain large numbers of *Protosalvinia huronensis* Dawson. The lower 13 feet, as shown in the highway cutting near the base of the hill, is a thin, light buff fissile shale, which weathers to a much lighter color than the shale above, and the weathered pieces are often stained red from iron. Dr. Orton stated that the base of the series was composed of "26 feet of white and blue clays."[1] All of this division is referred to the *Ohio shale*, which in Dr. Orton's section is called the Huron shales,[2] but they probably represent the Huron, Erie, and Cleveland shales of northern Ohio. The thickness of 332 feet is the same in the two sections - - - - 332 349

This formation was named the Ohio black slate by Andrews in 1870, and described as extending from the "Ohio river hills in the vicinity of Rockville, Adams county," northward to the hills at Chillicothe, spreading itself across the upper part of the Scioto valley and "resting upon the Corniferous limestone in the vicinity of Columbus."[3] In 1879 Professor Lesley applied the term Ohio conglomerate to the one occurring at the base of the Pennsylvanian or Carboniferous series in Ohio, stating that the Sharon conglomerate "is undoubtedly part (or the whole) of the *Ohio conglomerate*."[4] While in 1894, Mr. George H. Eldridge apparently named a Cretaceous formation in central Colorado, the Ohio formation evidently, from exposures on both sides of the Ohio creek in the southeastern part of the Anthracite quadrangle.[5] Of course both of these names are clearly synonyms of Andrews's "Ohio black slate," which in later years has generally been shortened to Ohio shale.

[1] *Ibid.*, p. 646. [2] *Ibid.*, p. 645.

[3] *Geol. Surv. Ohio*, "Pt. II, Rept. of Progress in the Second Dist.," p. 62.

[4] *Second Geol. Surv. Pa.*, Q^2, 1879 (?), Preface, p. 34, and see p. 29. Also see Q^3, 1880, pp. 56 f., 45 f.

[5] *Geological Atlas U. S.*, Folio 9 — Anthracite-Crested Butte Folio, pp. 6, 7. In the legend of the geologic sheets, save one, it is called "Ohio creek formation;" but in the text and on the "Columnar section" the name is given as "Ohio formation."

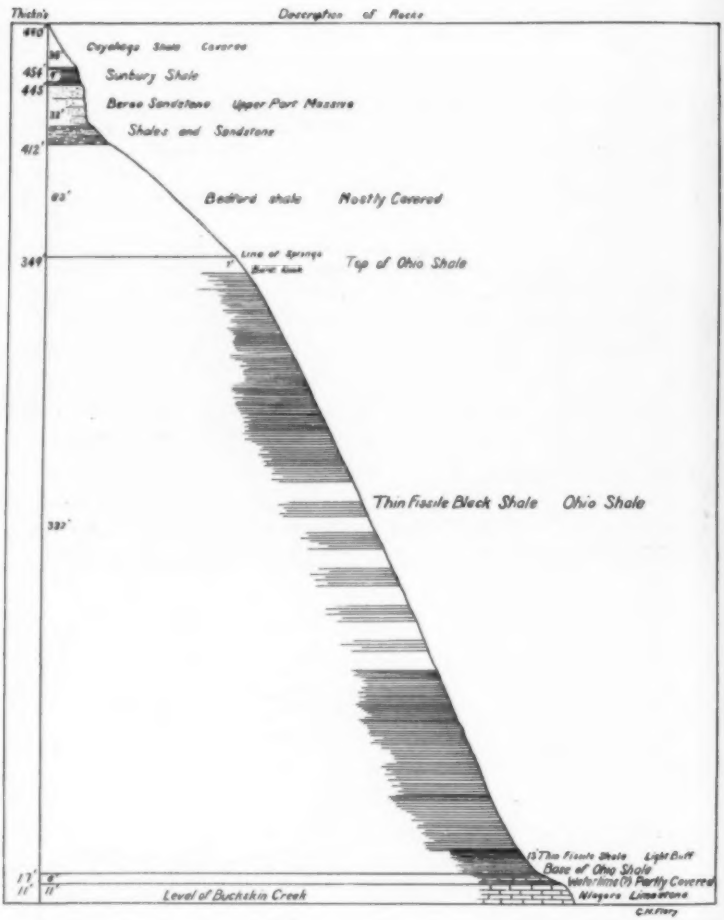
2.	Partly covered slope below the highway; but there are some thin projecting pieces of limestone. This zone probably represents the *Waterlime* or *Lower Helderberg*; but on account of scanty outcrops its correlation was not definitely settled. Above the railroad bridge the Waterlime is quite well exposed on the bank, between the railroad track and the highway. The rock is of a drab color, and some of the weathered layers are very rough. Part of the layers are quite sandy, and some of them are a form of breccia. Fossils occur; *Leperditia* is quite common in some of the layers, a few specimens of *Streptorhynchus hydraulicum* Whitf. were found, and a fairly large Gastropod shell - - - - - - - - - - - - -	6	17
1.	Massive light gray to drab limestone on the banks of Buckskin Creek to water level. A section of a shell, apparently *Pentamerus*, was found, while on the opposite bank of the creek above the railroad bridge imperfect impressions of shells, apparently *Megalomus*, were seen, so that this zone probably belongs in the upper part of the *Niagara limestone* - - - - - -	11	11

This section was briefly described by Dr. Orton,[1] the total thickness of which he made 500 feet, while in the above section it is 490 feet. He gave the thickness of the Niagara and Helderberg (Waterlime) limestones at the base of the hill as *each* 15 feet in thickness, which is some 10 or 12 feet greater than it can possibly be at this locality. Dr. Orton gave the Huron shales as 332 feet in thickness, the Waverly shales as 50 feet, the Waverly quarry courses as 31 feet, the Waverly black slate as 15 feet, which is probably nearer the actual thickness of the formation than the statement in the above section; still, as a matter of fact, but 9 feet are shown in the quarry, and for the upper beds of Waverly group 42 feet, but it is true that beyond the highway the hill is somewhat higher than at the point where my section terminated. A diagrammatic section of this hill is given in accompanying figure (Benner's Hill Section).

Stony Creek.—The Benner's Hill section is near the western line of Ross county, and the other outcrop in this county selected for consideration is one in the Scioto valley in its southeastern part. Stony Creek is a western tributary of the Scioto river, which it enters near the middle point of the eastern line of Franklin township.

[1] *Ibid.*, p. 645.

BENNER'S HILL SECTION



The Canal pike crosses Stony Creek at a point eight miles southeast of Chillicothe and eleven miles northeast of Waverly. A short distance below this highway bridge the viaduct of the Norfolk & Western Railroad crosses the creek, and on its southern bank a few rods above the viaduct is an interesting

FIG. 2.—Contact of Berea grit and Sunbury shale on Stony Creek, Ross county. The thin, even layers of shale at the base of the Sunbury project beyond the Berea grit.

outcrop of the Sunbury shale, Fig. 2. The following section of the bank was made at this locality:

STONY CREEK SECTION.

No.		Thickness feet.	Total thickness feet.
4.	A projecting ledge of thin bedded brownish sandstone occurs below the highway; the remaining portion of the bank covered to the road - - - - - - - - - - - -	¼	45+
3.	All thin black shale, in no particular respect differing from the Sunbury shale of central and northern Ohio. This outcrop forms the middle part of the bank just below the highway as it goes over the ridge south of the N. & W. viaduct. The *Sunbury shale*		

	with one of the thickest outcrops known in the state. The black shale is also shown by the side of the highway above the cliff as it descends the slope to the northwest - - - - - -	28—	45
2.	Massive sandstone, brown on weathered edge, with a thickness of 1 foot 8 inches. Then thin sandstone at top, olive shales in middle, and thin sandstone at the base, with a total thickness of 1 foot 5 inches. At the bottom a massive, fine-grained sandstone, 1½ feet thick. The total thickness of this zone is 4 feet 7 inches, and it was regarded by Dr. Orton as representing the Waverly quarry courses[1] or *Berea grit.* If this correlation be true, then there is to be noted a remarkable thinning in the formation when compared with the Benner's Hill section or the quarries in the vicinity of Waverly - - - - - - - - - - -	4½+	17
1.	Bluish to bluish-gray shales, with thin layers of sandstone, to the creek level. Some of the layers of sandstone show fine examples of ripple marks, and one layer about 5½ feet above the base has a thickness of 6 inches. This zone was referred to the Waverly shales by Dr. Orton, who stated that "the uppermost 25 feet of the Waverly shales appear here."[2] The base of this section is at the creek level on the upper side of the viaduct, which is hardly more than 4 feet above the level of the Scioto river, so there is scarcely any opportunity for an exposure of 25 feet of these shales at this locality. It is not improbable if the rocks were exposed to a greater depth at this point that thicker sandstones would be shown and all this lower part of the section might be referred to the *Berea grit.* The thin sandstones with beautiful ripple marks rather support this inference, since similar ripple marks occur so generally in the lower part of this formation and not in the upper part of the Bedford shale - - -	12½	12½

This section was briefly described by Dr. Orton, who reported "twenty-seven feet of the Waverly black slate, the heaviest section of this stratum yet reported in southern Ohio,"[3] which is practically the same as that obtained by the writer.

The bluish-gray shales with thin alternating sandstones are exposed on the banks of the creek above and below the highway bridge, while the lower massive stratum of the Berea grit is shown at the top of the bank immediately east of the bridge.

Another section was measured on the south bank of Stony

[1] *Ibid.*, p. 650. [2] *Ibid.*, p. 650.

[3] *Ibid.*, p. 650; also see p. 624, where it is stated that this is "the best section of it to be found in all the Scioto valley."

Creek, about one-half mile above the former, on the Wolf farm, which is as follows:

No.		Thickness feet.	Total thickness feet.
7.	At least 18 feet of thin even black shale is shown; the upper part of which is much weathered and broken and finally concealed by soil. The thin, even layers of the lower part are finely exposed, and there is a sharp and clearly shown line of contact between the shale and the underlying sandstone. *Sunbury shale*	18	29½
6.	Massive rather fine-grained bluish-gray sandstone, at top of *Berea grit*, which has a tendency to split into irregular layers, and in places there are shaly partings. Base of heavy stratum	3 1/3	11½
5.	Blue to bluish-gray arenaceous shales and thin sandstones	3⅙	7⅓
4.	Blue sandstone stratum of variable thickness	½±	4¾
3.	Bluish arenaceous shales and thin sandstones	1¾	4¼
2.	Bluish-gray compact sandstone, which is sometimes concretionary and of somewhat variable thickness	1½	2½
1.	Bluish shales and thin sandstone to bed of creek; the sandstone very much ripple marked	1+	1

It appears to the writer that the first six numbers of the above section may be referred to the Berea grit instead of simply the massive 3½ feet of sandstone — No. 6 — immediately below the Sunbury shale. It is true that a considerable part of the rocks below No. 6 are shales; but the sandstones are thicker than in the first section, and this extreme development of shales on Stony Creek is thought to be simply a local phase of the formation. The above section is shown in Fig. —, where the massive 3½ feet of sandstone at the top of the Berea forms a conspicuous layer across the middle part of the halftone, just above which is seen the projecting layer of thin, even-bedded black shale at the base of the Sunbury.

On the east fork of Stony Creek, about one mile above Wolf bank, are ledges of rather bluish-gray sandstone alternating with layers of thin sandstones, which are ripple marked. This is an outcrop of the *Berea grit*, and in the field to the west, and somewhat higher, are the thin black *Sunbury shales*.

Waverly.—The rocks of the Waverly series were named from outcrops in the vicinity of Waverly, to which Professor C. Briggs, Jr., in 1838, gave the name *Waverly sandstone series*,[1] to the rocks

[1] *First Ann. Rept. Geol. Surv. Ohio*, p. 80.

occurring between the "argillaceous slaty rock, or shale stratum," now known as the Ohio shale, and the "conglomerate" which lies at the base of the Coal-measures.

In Dr. Orton's description of the geology of Pike county, he termed the shales between the top of the Ohio black slate and the base of the higher massive sandstones the *Waverly shales*,[1] a name apparently proposed by him; while the sandstone which is now known to be the continuation of the Berea of northern Ohio, was named the *Waverly quarry system*.[2]

The old Waverly quarries, formerly operated by Emmett, were mainly on the road toward Pee Pee, and are no longer actively worked. The same sandstone, however, is now quarried along the line of the Ohio Southern railroad up to the Crooked Creek valley to the northwest of Waverly. One of the nearest quarries to Waverly is that of the Southern Ohio Stone Co., on the Ohio Southern railroad, 1½ miles above the Waverly station, or about 2 miles up the Farmersville pike, northwest of Waverly. This quarry has been open some seventeen years, and for a time was worked by the railroad company. The detailed section of the Berea sandstone in this quarry is given below.

SECTION OF THE SOUTHERN OHIO STONE COMPANY QUARRY.

No.		Thickness feet.	Total thickness feet.
14.	*Sunbury black shale*, 2 feet shown in pit above the top of the quarry	2	65
13.	Covered interval of 1 foot 2 inches	1⅙	63
12.	Thin-bedded sandstone at the top of the *Berea sandstone*	2	61½
11.	Rather thin sandstone on quarry face, but thickens under cover, and will make quarry stone	5	59½
10.	Bridge stone, 22-inch stratum	1½	54½
9.	Shaly to thin-bedded sandstone	3	53
8.	Good sandstone in three layers, upper course 12 inches, middle one 18 inches, lower 15 inches	3¾	50
7.	Shaly sandstone	1$\frac{3}{12}$	46¼
6.	Good sandstone	1½	44½
5.	Shaly layers to thin-bedded sandstone; but the greater part of the stratum is concretionary with some shale — the "bowlder layer" of the quarry men	6	43

[1] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. I, 1874, p. 619. [2] *Ibid.*, p. 621.

4.	The best stone in the quarry, which is sawed and shipped extensively; the upper course 16 inches and the lower one from 18 to 20 inches in thickness. Base of quarry - - - - - -	3—	37—
3.	Course of 32 inches - - - - - - - - - - -	2⅔	34
2.	Good sandstone, which is apparently the base of the *Berea sandstone* - - - - - - - - - - - - -	1⅓	31⅓
1.	From base of the Berea sandstone covered slope to mouth of well directly below quarry at house of Mr. L. S. Risley. According to Mr. Combs, the top of the Ohio black shale was struck at a depth of from 30 to 40 feet in this well, which gives a thickness from 60 to 70 feet for the Bedford (Waverly) shale. Dr. Orton gave the thickness of the Waverly shales in Pike and Ross counties as 90 feet[1] and it is not improbable that the top of the Ohio black shale occurs at a greater depth in the well than reported above - - - - - - - - - - -	30	30

The above section gives nearly 32 feet for the thickness of the Berea sandstone, and 60 to 70 feet for that of the subjacent Bedford shale. The general color of the building stone is gray, although sometimes rather buff or even greenish on weathered surface. There are layers showing ripple marks and also bluish to greenish shales, some of which are much iron stained. The general appearance of the stone is quite similar to that of the Berea sandstone in central Ohio.

The slope of the hill above the sandstone is very gradual, and the Sunbury or Waverly black shale does not make conspicuous outcrops; but its occurrence immediately above the sandstone is shown in the small pit above the quarry, where two feet of its lower part is exposed.

On the "General section of the Waverly system in Pike and Ross counties"[2] Dr. Orton gave, as occurring between the Waverly quarries and the Waverly black slate, a zone of "shales with concretions of iron ore" 30 feet in thickness. This zone is apparently not described in the text, where it is stated that the Waverly black slate comes "immediately above the Waverly quarries,"[3] and no indication of this intermediate shale was seen in the sections which were examined by the writer.

[1] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. I, 1874, Fig. 1, op. p. 615, and Fig. 2, op. p. 618.

[2] *Ibid.*, Fig. 1, op. p. 615, and Fig. 2, op. p. 618. [3] *Ibid.*, p. 624.

About 1½ miles farther up the railroad, at Peck, are the extensive quarry and mill of the Waverly Stone Co., which also obtains its stone from the Berea sandstone. There is also a small quarry located on the eastern side of the valley, called Peck's quarry.

Mr. I. Combs, the superintendent of the Southern Ohio Stone Co. has not seen the Waverly brown sandstone, which occurs near the base of the Cuyahoga shales, overlying the Sunbury shale, in the hills bordering Crooked Creek; but the locality east of the river, where it caps the hill on the Gregg farm, is well known to him. He also reported excellent outcrops of it farther north on the eastern side of the river, about one mile below the Omega river bridge. Dr. Orton reported this sandstone as 10 feet in thickness on his section of the "Waverly System in Pike and Ross counties" with 35 feet of blue shales between it and the top of the Waverly [Sunbury] black slate.[1] He correlated it with the stone obtained high in the bluffs on the northern side of the Ohio river near Buena Vista and called it the Buena Vista stone,[2] which correlation is restated in his last account of the geological scale of Ohio.[3]

Buena Vista.—The extensive quarries near the head of an east branch of Lower Twin Creek, some five miles northwest of Beuna Vista, were studied. A tramway extends from the town to the quarries, and a highway may be followed to No. 4 on the tramway, within about one mile of the older quarries, which are no longer worked. On the bank of the creek, just above No. 5 of the tramway, is a good exposure of the upper part of the Ohio shale, which begins at creek level and extends up the bank for 24 feet, when the shales are covered by soil. Two species of *Lingula* were found near the top of these shales, the most common one resembling quite closely *Lingula Williamsana* Girty, while a larger species is also found lower in the bank. A sandstone ledge in the lower part of the Bedford is shown not much farther up the bank.

[1] *Ibid.*, Fig. 1, op. p. 615, and Fig. 2, op. p. 618.

[2] *Ibid.*, Fig. 1, op. p. 615, Fig. 2, op. p. 618, and p. 626.

[3] *Ibid.*, Vol. VII, 1893, p. 31.

On the eastern side of the creek at this locality is an old incline, at the top of which is an unworked quarry. The lower part of this quarry shows the thin, black, laminated Sunbury shale, the loose pieces of which are conspicuous on the dump near the top of the bluff, as seen from the creek valley below. Above the Sunbury is olive-colored shale, capped by the Buena Vista quarry stone, in two layers, or "City ledge" as the outcrops of this stratum near Rockville, between one and two miles below Buena Vista, were termed in 1838 by Professor John Locke, in his geological account of Adams county.[1]

Some distance up the tramway from No. 5 is the incline in present use, the foot of which is barometrically 130 feet below the base of the "City ledge" at its top. Perhaps 15 to 20 feet above its base are fairly heavy sandstone layers in the Bedford formation, which, in the Ohio river bluffs, contains much more sandstone than in the central part of the state. The Berea sandstone is shown at the side of the incline near its top, where the top of the formation is marked by a massive stratum, 1 foot 9 inches in thickness, below which are thinner bedded and shaly layers. The Berea is light gray in color and fairly massive, above which in the soil by the side of the incline, are numerous pieces of the Sunbury black shale. From the top of the Berea sandstone on the incline to the base of the "City ledge," or Buena Vista sandstone, opposite the top of the plane is 21 feet. The excavation for the cistern at the head of the inclined plane was made in the Sunbury shale, large quantities of which are shown on its dump.

The Buena Vista stone forms a prominent ledge just back of the top of the plane, and it has been worked more or less extensively for some distance along this bank of the stream toward its head. Not far from the present upper limit of the quarry, the "City ledge" and overlying shales furnished the following section:

[1] *Second Ann. Rept. Geol. Surv. Ohio*, 1839 (?), p. 263. The name was given because the stone was extensively quarried and used in the city of Cincinnati (see page 264).

SECTION OF BUENA VISTA FREESTONE QUARRY.

No.		Thickness feet.	Total thickness feet.
7.	Soil	3 ±	24½
6.	Very argillaceous, no grit, olive, bluish and reddish colored shale, some of it mottled	8½	21½
5.	Mottled bluish and reddish argillaceous shale, containing concretions and concretionary layers. In places mainly reddish in color	2	13
4.	Bluish argillaceous, rather compact shale	5½	11
3.	Top of fine-grained massive Buena Vista sandstone or "City ledge." The weathered top of this layer is frequently of rather bluish to greenish tint and covered by a mass of beautiful specimens of *Spirophyton*, the tubes and fronds of which extend down for a few inches into the upper part of this layer	3+	5½+
2.	Greenish argillaceous shale parting	2½ in.	2½+
1.	Lower layer of Buena Vista sandstone; a brownish to bluish-gray, fine-grained massive sandstone which emits a decided petroleum odor when freshly struck. Also frequently of light gray and sometimes reddish-brown tint. Base of the "City ledge," which has a thickness of 5 feet 7½ inches in this quarry. This compact freestone is a valuable sandstone, and in this region it is much more important commercially than the Berea sandstone	2½	2½

The massive Buena Vista sandstone with the overlying shales are shown in Fig. 3.

The large blocks of Buena Vista sandstone from these quarries, containing numerous specimens of *Spirophyton*, apparently show that these markings are made by worms. Extending down into the stone from the fronds, which occur on or near the top surface of the stratum, at various angles are tubes, some of which are open and others are filled with clayey material. These tubes are apparently the holes in the fine sand in which marine worms lived. Crawling to the surface, and back again and about the opening of the tube, they made the smoothed and grooved space which has been termed the frond, as it was supposed to represent a sea weed buried in the sand.

It is clearly evident that the Sunbury shale (Waverly black slate) extends to the Ohio river, probably with a thickness of between 15 and 16 feet as given by Andrews,[1] above which is 5

[1] *Geol. Surv. Ohio*, Pt. II, "Rept. Prog. Sec, Dist." [in 1869], 1870, p. 65; and see his "Section of Waverly rocks from the great Black slate of the Subcarboniferous limestone, as seen on the Ohio river," on "Map showing the Lower Coal-measures."

feet 4 inches of fire clay and blue and drab shale, as given on Andrew's section. His section gives a thickness of 20 feet 9 inches from top of sandstone (Berea) to the base of the "City ledge" (Buena Vista stone), and my section for the same portion of the Waverly is 21 feet, or 3 inches greater, which is a very close agreement when it is remembered that the location

FIG. 3.—The two layers of Buena Vista sandstone and overlying shales on Lower Twin Creek, northwest of Buena Vista.

of the two sections is two miles or farther apart. Succeeding the zone of fire clay and shale is the Buena Vista stone or "City ledge," in two layers separated by a shale parting of 2½ inches, with a total thickness of 5 feet 7½ inches.

Professor Locke gave the thickness of the "City ledge" at Rockville as 2½ feet, and stated that it had "a stratum of shale about 15 feet below it," the context showing that he evidently meant the shale had a *thickness* of about 15 feet, "and another of about the same thickness above it."[1]

[1] *Second Ann. Rept. Geol. Surv. Ohio*, p. 264.

The first distinct geographical name applied to the Sunbury shale was the "Waverly black slate," by Andrews, in 1870,[1] who gave its general thickness as 16 feet and its base as 137 feet above the top of the Ohio black slate, on Andrews' "Section of Waverly rocks . . . . on the Ohio river," however, the thickness of the Waverly black slate was given as 15½ feet, and its base as 134 feet above the top of the Ohio black slate.[2] The thickness of the "City ledge" was given by Andrews as 3 feet 5 inches near Rockville and 4½ feet on the Flagg land, probably on Lower Twin Creek,[3] and in 1871, in his "Section along the Ohio river from Adams to Lawrence counties," he reported it as 4 feet thick.[4]

Dr. Orton, in 1882, published a general statement concerning the formations in the vicinity of Buena Vista, in which he stated:

> The Bedford shale is still distinguishable with normal thickness, but carrying a relatively larger proportion of stone than to the northward. The Berea grit is clearly recognizable in the so-called "cliff stone," which has been quite largely worked here. The Berea shale (Waverly black shale) is a constant guide to the true order. The Buena Vista stone makes, as elsewhere, the base of the Cuyahoga shale, which is charged with more frequent freestone beds than to the northward.[5]

Finally, Herrick, in 1891, in his section of the southern exposures of the Waverly near Portsmouth, gave the thickness of the Berea black shale (Sunbury) as 15 feet, below which was from 30 to 40 feet of Berea grit flags.[6]

Vanceburg.—On the Kentucky side of the Ohio river about five miles below Buena Vista is Vanceburg at the eastern end of which is a steep and high hill known as Alum Rock.

[1] *Geol. Surv. Ohio*, Pt. II, "Rept. Prog. Sec. Dist." [in 1869], p. 66.

[2] *Ibid.*, "Map showing the Lower Coal-measures."

[3] *Ibid.*, p. 66.

[4] *Proc. Am. Phil. Soc.*, Vol. XI, p. 245.

[5] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXX, p. 174.

[6] *Bull. Geol. Soc. Amer.*, Vol. II, p. 40.

SECTION OF ALUM ROCK.

No.		Thickness feet.	Total thickness feet.
6.	Top of massive sandstone, capping first knob, which lithologically closely resembles the "City ledge" of Buena Vista region, while on top and in the upper part of the stratum are numerous specimens of *Spirophyton* similar to those described in the Lower Twin Creek quarry. The top of this sandstone, however, is 51 feet above the top of the Berea sandstone, while in the Lower Twin Creek it is only 26½ feet, so that it appears somewhat doubtful whether these two exposures are in the same layer. Loose blocks of sandstone containing *Spirophyton* occur at the elevation of 27 feet above the top of the Berea sandstone, and this layer perhaps represents the horizon of the "City ledge" as shown to the northwest of Buena Vista. All of this slope below the massive sandstone at top is covered - - - - -	38	423
5.	Thin, black, even argillaceous shale, 13 feet shown before it is covered by soil. *Sunbury (Waverly black shale)* - - -	13	385
4.	Top of massive *Berea sandstone;* some of the layers thick, light gray in color, rather course grained and weathering brownish. Some of the layers have magnificent specimens of ripple marks. The layer just below the top one is 3 feet thick, and on the top surface are splendid ripple marks - - - - - - - -	21	372
3.	Perhaps the rocks are mainly gray or greenish to bluish-gray shales, weathering to an iron color; but there are sandstone layers, some irregular or concretionary, often ripple marked, frequently thick, one of them 26 inches, and *Spirophyton* occurs. *Bedford formation* - - - - - - - - - - -	75	351
2.	Covered. Plenty of yellowish iron stained arenaceous shales in soil. Perhaps all or the greater part of this zone belongs in the Bedford formation - - - - - - - - - - - -	21	276
1.	Black thin layered Ohio shale. Near the top of the shales are a few fossils, as a large *Lingula*. Partly covered slope, but probably all Ohio shale to the level of the Chesapeake and Ohio railroad; 255 feet by the barometer from railroad level to highest outcrop of shale - - - - - - - -	255	255

The Alum Rock section clearly shows that the Sunbury shale crosses the Ohio river, and has a thickness of at least 13 feet in the vicinity of Vanceburg. It was not followed farther south in Kentucky and at present it is not known how far it can be traced in that state.

NORTHERN OHIO.

From near Sunbury, Delaware county, northward there are no reported surface exposures of the Sunbury shale across Morrow,

Crawford, Richland, Huron, and Lorain counties to the western part of Cuyahoga county. As a rule, however, the older formations of this part of the state are deeply covered by drift deposits, so that outcrops are infrequent, and it is not strange that this thin deposit of shale has not been reported. Its continuation, however, appears to be conclusively shown by the records of numerous wells drilled in these counties, in which a black shale of variable thickness was penetrated just above the Berea sandstone. Some of these wells are mentioned below, in all of which the Sunbury (Berea) shale was noted at its proper stratigraphic position, immediately above the Berea grit. At Mt. Vernon, Knox county, the top of the Berea grit is reported at a depth of 470 feet;[1] in Richland county, at Mansfield, it is 640 feet in depth, with 40 feet of Sunbury shale above;[2] at Crestline 113 feet in depth;[3] at Shelby 141 feet,[4] with 23 feet of Sunbury shale on top; at New London, Huron county, 165 feet;[5] at Wellington, in Lorain, 138 feet, above which is reported 30 feet of black shale;[6] and at Belden from 10 to 25 feet of Sunbury shale.[7]

Berea.— Dr. Newberry in his "Report on the geology of Cuyahoga county," stated that at Berea, in the western part of the county, "that portion of the Cuyahoga shale which immediately overlies the Berea grit contains myriads of *Lingula melie* and *Discina Newberryi*,"[8] but there was no suggestion of separating this fossiliferous deposit from the Cuyahoga shale. In 1875 Meek mentioned "the dark shales of Berea" in an explanation of a figure of *Discina* (*Orbiculoidea*) *Newberryi* from that locality, and used the expression "Berea shale."[9]

Quarry No. 6 of the Cleveland Stone Company at Berea furnishes the following section:

[1] *Rept. Geol. Surv. Ohio*, Vol. VI, 1888, p. 366.
[2] *Ibid.*, p. 365.
[3] *Ibid.*, p. 303.
[4] *Ibid.*, pp. 316 and 365.
[5] *Ibid.*, p. 440.
[6] *Ibid.*, p. 348.
[7] *Ibid.*, p. 332.
[8] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, 1873, p. 185.
[9] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. II, Pl. XIV, explanation of Figs. 1c and 1d.

SECTION OF QUARRY NO. 6.

No.		Thickness feet.	Total thickness feet.
4.	*Erie clay* to top of bank	11	50
3.	Top of *Sunbury* (*Berea*) *shale.* It is mainly a black, quite massive bituminous shale; but some of it as weathered is rather bluish in color. Thin layers contain specimens of *Lingula melie* H., but they are not abundant in that portion of the shale which is exposed at this locality	8⅔	39+
2.	Probably all of this zone is in the *Sunbury shale;* but it is partly covered and the contact with the subjacent Berea grit is poorly shown	3	30½—
1.	Top of the *Berea grit.* A layer from 7 to 16 inches in thickness, and perhaps more, forming the upper part of the Berea sandstone is hard, contains plenty of iron pyrites, is not valuable for stone and weathers into a somewhat shaly layer	27½—	27½—

There are four prominent courses of the Berea grit as worked in this quarry, with the following thicknesses: Course No. 4, including the pyrite layer at the top, 5 feet 4 inches; course No. 3, 6 feet 8 inches; course No. 2, 7 feet 1 inch; No. 1, 6 feet 4 inches. Below this 2 feet of sandstone is shown at the bottom of the quarry without reaching the base of the Berea grit.

In quarry No. 8, adjoining the one just described, they have drilled into the Berea sandstone to the depth of 52 feet, and Newberry stated that in Cuyahoga county it is "something like 60 feet in thickness."[1] In this quarry there is more shaly sandstone at top than in No. 6 and a clay pebbly layer near the top contains a few specimens of *Camarotœchia.* The following section is for the eastern end of the quarry, with the exception of its upper portion which was obtained on the northern bank.

SECTION OF QUARRY NO. 9.

No.		Thickness feet.	Total thickness feet.
4.	*Erie clay* to top of bank	10½	91¼
3.	On the northern wall black shale or grayish-black when weathered	13¼	81¼
2.	Black bituminous shale, some of it with a bluish tint, containing numerous specimens of *Lingula melie* Hall and some of *Orbiculoidea Newberryi* (Hall) Herrick. *Sunbury shale*	11	68

[1] *Loc. cit.*, p. 186.

1. Top of *Berea grit.* This course, No. 7, composed of shaly sandstones layers generally thin and containing plenty of iron pyrites; not valuable quarry stone, 5 feet two inches. Course No. 6, 4 feet; course No. 5, 8 feet 4 inches; course No. 4, 7 feet 7 inches; course No. 3, 6 feet 3 inches; course No. 2, 10 feet; course No. 1, 15 feet 6 inches. Floor of the quarry but not the bottom of the grit. Courses 1 to 6 inclusive are all composed of good massive quarry stone with a total thickness of 51 feet 8 inches. When freshly quarried the stone is of light gray color; but on weathered surfaces it is not infrequently stained from the decomposition of iron pyrites - - - - - - - - 57 57

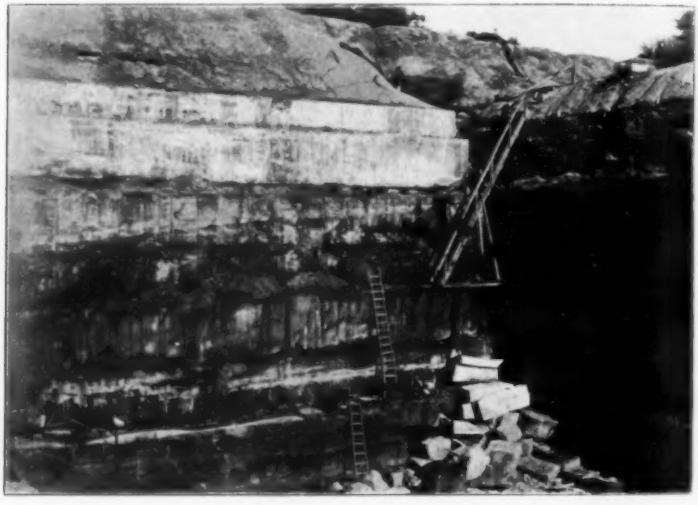


FIG. 4.—Berea grit with superjacent Sunbury shale in quarry No. 9, at Berea.

This section shows that there is not such a marked and sharp lithologic change from the Sunbury to the Cuyahoga shale as is found in the bluffs of the Ohio river or is shown in sections farther east, but a more gradual transition. This quarry is shown in Fig. 4, the greater part of which is the Berea grit, but capped by the Sunbury shale, and fossils are abundant in the zone indicated by the man.

Bedford.—In the vicinity of Bedford, in the southern part

of Cuyahoga county, on the banks of Tinker's Creek, are several good vertical sections from the Bedford shale or Berea grit into the Cuyahoga shale. Three of these will be given, and their comparison will show some lithologic variation in a comparatively short distance. The following is a section of the south bank of Tinker's Creek under the bridge of the Akron, Bedford & Cleveland electric road.

SECTION AT THE A. B. & C. ELECTRIC BRIDGE.

No.		Thickness feet.	Total thickness feet.
5.	Gray to bluish-gray shale, with an occasional blackish streak, which breaks into very small pieces as weathered and shown on the upper part of the bank. No fossils were found - - - -	10⅝	51
4.	Alternating shales and sandstones of bluish-gray color, the sandstone predominating. *Cuyahoga shale* - - - - - -	8¼	40¼ —
3.	Thin argillaceous bluish-gray shales splitting into small pieces. At the base a blackish bituminous shale 1 inch in thickness, which splits into thin, smooth layers, and contains *Lingula melie* Hall. In lithologic appearance only the 1 inch of blackish shale at the base of this shale zone resembles the *Sunbury shale* of southern and central Ohio and the eastern part of Cuyahoga county, and this is not as black as typical Sunbury shale. It is probable, however, that the blue color and other characters of this shale are a local variation, and that all of this zone may be referred to the Sunbury shale. If not, then at this locality it has thinned to the 1 inch of black, fossiliferous shale noted at the base of the zone - - - - - - - - - -	5 1/12	32 —
2.	Top of *Berea grit;* massive grayish, rather coarse-grained sandstone - - - - - - - - - - - -	21½	26½
1.	Shaly to thin-bedded blue sandstone to creek level, all of which is in the Berea grit. There are plenty of ripple marks on the sandstone in the bed of the creek - - - - - -	5	5

Farther down the stream the following section is shown on the eastern bank of the creek a little above the Bedford rolling mills.

SECTION ABOVE BEDFORD ROLLING MILLS.

No.		Thickness feet.	Total thickness feet.
3.	Gray, fine-grained, thin-bedded sandstone, alternating with layers of shale, the sandstone predominating. Base of *Cuyahoga shale* - - - - - - - - - - - - -	7⅓	35
2.	Thin-bedded argillaceous shales which are mainly of gray color, but passing from blackish-gray to black bituminous shales. At the base *Lingula melie* H. and *Orbiculoidea* occur sparingly. *Sanbury shale* - - - - - - - - - - - -	6	27⅔

1. Massive *Berea grit;* some of the upper layers thin-bedded, partly covered slope to creek level, and only about the upper half of the formation exposed - - - - - - - - -	21⅗	21⅗

The best section of these formations in the vicinity of Bedford, however, is that on the northeast bank of Tinker's Creek, between the Bedford rolling mills and the Cleveland and Pittsburgh railroad viaduct, Fig 5. A dam for an electric light plant

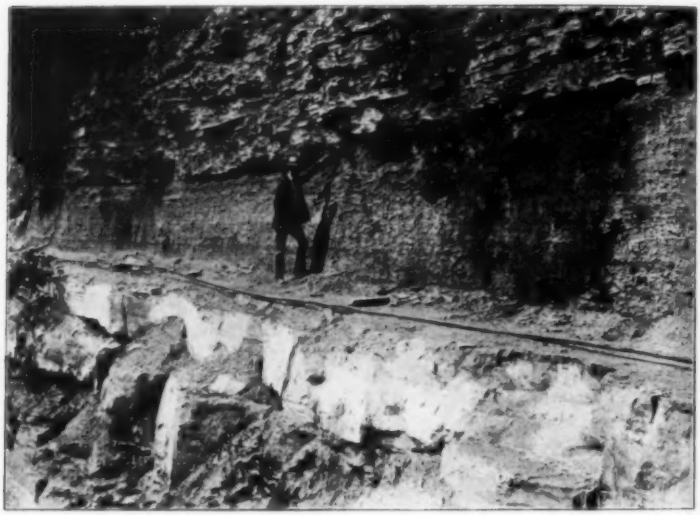


FIG. 5.—Sunbury shale above C. and P. R. R. viaduct, Tinker's Creek, Bedford. The man is standing on top of the Berea grit and indicating with his hand the contact of the Sunbury and Cuyahoga shales. The thin sandstones in the lower part of the Cuyahoga are clearly shown.

is being constructed not far below this locality so that later the lower part of the section may be concealed by water.

SECTION ABOVE THE C. & P. RAILROAD VIADUCT.

No.		Thickness feet.	Total thickness feet.
4.	Mainly thin-bedded, light gray sandstone, with shale partings to top of the bank. At base thin-bedded, light gray, fine-grained sandstone. Base of *Cuyahoga shale* - - - - -	7½	71—

3.	Blackish shale near top of zone. Very fine argillaceous shale which is mainly bluish-gray to gray in color, but with some blackish layers. It is finely shown on the bank above the quarry. *Sunbury shale* - - - - - - - - - - - -	6	63⅓
2.	Top of *Berea grit* at top of quarry. Light to dark gray or rusty-brown color, rather harder and finer-grained sandstone than the lower courses, 3⅙ feet. Massive, light gray, coarse-grained grit, often weathers yellowish, 3⅔ feet. Light gray, or frequently weathered to iron color, thin-bedded to shaly sandstone, 3⅙ feet. Massive, light gray, coarse-grained sandstone to grit. Ripple marks occur in lower part, 29⅓ feet - - -	39⅓	57⅓
1.	Contact of *Berea grit* and *Bedford shale*. Upper part of Bedford composed of bluish-gray argillaceous shales. Lower shales alternating with thin layers of sandstone, 1 inch or more in thickness, to creek level - - - - - - - - -	18	18

It appears that No. 4 of Dr. Newberry's "Section of strata at Bedford," which he described as a gray shale from four to six feet thick and classed in the Berea grit,[1] is the equivalent of what is called the Sunbury shale in the above sections. Dr. Newberry also included the superjacent zone of thin bedded sandstone (No. 3 of his section) in the Berea. It is the writer's impression that he was in error in this particular, and that the top of No. 5 of his section should be considered as the line of separation between the Berea grit and the overlying formation, now called the Sunbury shale, but in the time of his reports considered as the base of the Cuyahoga shale. The zone termed the Sunbury shale in the above sections is composed of a very argillaceous, thin-bedded shale, mainly gray to bluish-gray in color, with bands of black shale. It appears to the writer that this shale represents the Sunbury shale of central Ohio, but that it has largely lost its black and bituminous character. Remove Nos. 3 and 4 from the Berea grit of Newberry's section and there remains but No. 5 of his section for the Berea, which he described as a "thick-bedded yellow sandstone with ripple marks," 45 feet in thickness; while in the above section we have a thickness of 39½ feet for the Berea. The Sunbury shale of the above section is well shown in Fig. 5, where the man is standing on top of the Berea grit and pointing to the line of contact of the Sunbury and Cuyahoga shales.

[1] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, 1873, p. 197.

Chagrin Falls.— In the eastern part of Cuyahoga county, on the bank of Chagrin River, above Chagrin Falls, is a fine outcrop of the Sunbury shale. The following section was made at the Goodale quarry opposite the paper mill above Chagrin Falls:

SECTION OF GOODALE QUARRY ABOVE CHAGRIN FALLS.

No.		Thickness feet.	Total thickness feet.
3.	Black, bituminous shale, which weathers on the edge frequently to a rusty color, and is a massive shale under cover. The lower foot of the shale contains immense numbers of *Lingula melie* H. and a smaller number of a large species of *Lingula* and *Orbiculoidea Newberryi* (Hall) Herrick. There are also fragments of fish and plants. The fossils are the most abundant in the lower foot of the shale, but they occur in considerable force for at least 2½ feet above the base, and specimens were collected in the shales at the height of 4 feet. *Sunbury shale* - -	11	20
2.	Top of *Berea grit.* Massive coarse-grained layer, friable rock, easily crumbling in the fingers, 3½ feet thick. At the lower end of the quarry the upper part splits into thin, rather irregular flags, and there is no massive layer at top. Thin bedded to shaly sandstone, part of which makes flagging. The flags show ripple marks, and some of the layers are worthless; 2½ feet exposed - - - - - - - - - - - -	6	9
1.	Covered to river level - - - - - - - - -	3±	3

This is the best locality noted in the Sunbury shale for collecting fossils, and attention was first called to it by Dr. Newberry.[1] The above section is shown in Fig. 6, where the man is standing on one of the layers of Berea grit and indicating with his hand the contact of the Berea and Sunbury shale.

Warren.—Across Lake, Geauga, Ashtabula, and Trumbull counties, there are comparatively few outcrops of the Sunbury shale, and as a rule even the Cuyahoga shale is concealed by drift deposits. On the bank of the Mahoning river, however, above Warren, are excellent outcrops of the Sunbury shale. One of these may be found on the eastern bank below the house of Alfred Fitch, rather more than one-fourth of a mile above the Water Works.

[1] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, 1873, p. 185.

FIG. 6.—Contact of Berea grit and Sunbury shale in Goodale quarry, Chagrin Falls, indicated by the man's hand.

SECTION ON MAHONING RIVER ABOVE WARREN.

No.		Thickness feet.	Total Thickness feet.
5.	Soil and clay		
4.	Sandy layers to sandstone		
3.	Bluish-gray compact sandstone. Base of *Cuyahoga formation*	¼	16¼
2.	Top of shale rather impure and sandy, perhaps in places 1 foot of sandy shale at top. Black to brownish-black shale, some of it very black and compact, in lithologic characters similar to the Sunbury shale. The lower part of the shale contains immense numbers of *Lingula melie* Hall and a smaller number of specimens of another species of *Lingula*. *Sunbury shale*	14	16
1.	Top of *Berea sandstone*. Fairly fine-grained, very uneven bedded sandstone, which contains a large quantity of iron pyrites. A little below, in thinner layers, are numerous ripple marks. The sandstone appears above water on the arch of a small anticlinal fold. At the time it was studied the upper 2 feet of the formation was exposed, while on the river bank, both above and below this locality, the Sunbury black shale runs down to water level	2±	2

On the same bank of the river about ¼ mile below the

section just described and a short distance above the Water Works is the following section, the rocks of which are apparently above those of the former section and in the lower part of the Cuyhoga formation.

SECTION ABOVE WARREN WATER WORKS.

No.		Thickness feet.	Total thickness feet.
7.	Soil and till		
6.	Apparently shale		
5.	Bluish-gray sandstone	¼ ±	16
4.	Soft bluish-gray, very argillaceous shale	2¾	15¾
3.	Compact layer of bluish-gray, fine-grained sandstone	¾ ±	13
2.	Blackish shales at top containing specimens of *Lingula*. The shales are mainly bluish-black; but contain thin bituminous layers, especially in the upper part, and alternating with the shales are thin layers of bluish sandstone, which are thicker near the base of the cliff, and some are slightly concretionary, weathering to a decided rusty color. Specimens of *Lingula* are numerous in the blackish shales near the top, and some were also collected in the blackish shales near the base of the section	11	12⅓
1.	At the upper end of the exposure, where the rise brings up the lower rocks, we find that below the shales of No. 2 are coarse arenaceous shales to bluish-gray sandstone, about 1⅓ feet shown. This stratum is apparently the sandstone zone occurring on top of the Sunbury shale. Level of Mahoning river	1⅓	1⅓

The prominent sandstone layer at the southern end of the cliff is 9 feet 10 inches above water level, and 420 feet farther north, at the northern end, 12 feet 4 inches above the water, giving a dip of 2 feet 6 inches for that distance to the southeast or at the rate of 31 feet per mile. This section is considered as in the lower part of the Cuyahoga formation, and shows that its lower shales are blacker than those near the base of the formation in northern and central Ohio, and somewhat similar to those of the subjacent Sunbury shale.

On the western bank of the Mahoning river, 1½ miles from the court house park in Warren, on the farm of Warren Brobst, the anticlinal fold already noted on the eastern bank brings up the Berea sandstone. At the base about four feet of Berea sandstone is shown above low water, which is mainly thin-bedded.

The layers are buff in color, more or less undulating, and some of them have ripple marks. Just above is the black Sunbury shale in the lower part of which are immense numbers of *Lingula melie* Hall, together with a larger *Lingula* which is not nearly so abundant.

Above Edgewater, a mile or more beyond the locality just described, is a rocky bank which shows the following section: At the base a blackish fissile shale, about eight feet in thickness; at the top of the shale is a thin sandstone, above which is another zone of shale, capped by a thin sandstone. The Berea sandstone is not shown at the river level and the exposed shales and sandstones apparently belong to the lower part of the Cuyahoga formation.

M. C. Read wrote the geological report of Trumbull county, and under the description of "the Cuyahoga shale" he stated that:

> In the bed of the Mahoning west of Warren, the abundance of *Lingulæ* and the lithological peculiarities indicate that the stream at this point cuts nearly through these shales, and that the Berea grit is to be found at no great depth below.[1]

From the above statement it is evident that Read did not find or recognize the Berea grit in the Mahoning river above Warren. It is of course possible that he did not visit the locality where the anticlinal fold crosses the river and brings up the Berea so that he did not see the top of the formation, or perhaps the water was considerably higher at the time of his work, and the sandstone was covered.

Mr. Read appears to have been confused regarding the horizon of the Berea grit near the state line, a point which has been elucidated by Dr. I. C. White[2] and Professor H. P. Cushing who identified the formation in the vicinity of Warren. Professor Cushing's statement is as follows: "North of Warren another sandstone appears directly under the black shale [the Sunbury or Berea shale] and is the equivalent of the lowest

[1] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, 1873, p. 504.

[2] *Second Geol. Surv. Pa.*, Q³, pp. 60 f., 62, 63 f., and Q⁴, pp. 77 f., 85, 86.

sandstone on the state line, of the *Corry* sandstone of Professor White in Pennsylvania, of the Berea of northern Ohio.[1]

Professor Cushing gave a section of the rocks through Warren in which the Berea shale (Sunbury) is given as 55 feet in thickness.[2]

It is evident that he included in the Berea shales the blackish ones which the writer has referred to the lower part of the Cuyahoga formation, for it seems to him that only the 14 feet of black shales exposed on the bank of the Mahoning river, and included between the top of the Berea grit and the base of the overlying 9-inch blue sandstone, are to be regarded as the equivalent of the Sunbury black shale as exposed at the typical localities of Sunbury, and in the bluffs of the Ohio river near Buena Vista.

Dr. Orton stated that "in Trumbull county of northeastern Ohio, the Berea [Sunbury] shale grows very thin and thus the upper quarry courses come down close upon the Berea grit."[3] Later he wrote:

> The Berea shale seems to be reduced in this region [Warren] to a thickness of about 8 or 10 feet. It is, however, well characterized by the Discina and Lingula which belong to the horizon. In many places it is almost entirely composed of these shells.[4]

While in describing the Berea grit in the vicinity of Cortland, 7 miles northeast of Warren, Dr. Orton stated:

> It is always overlain by a thin but very black fossiliferous bed of the Berea shale. An excellent section is furnished in the banks and the bed of Walnut Creek, within the limits of the village of Cortland, and a half-mile below. At the junction of Walnut and Musquito creeks, the flag-rock that makes the upper bed of the Berea is found in the bed of the stream. It is covered by 8 feet of Berea shale, very black and crowded with its characteristic fossils.[5]

Mr. John F. Carll, who described such a large number of oil well sections for the Pennsylvania survey, regarded the Berea

[1] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXXVI, 1888, p. 215.

[2] *Ibid.*, p. 214, No. 3.

[3] *Ibid.*, Vol. XXX, 1882, pp. 173, 174.

[4] *Rept. Geol. Surv. Ohio*, Vol. VI, 1888, p. 321.

[5] *Ibid.*, p. 331.

grit as probably identical with the Pithole grit of Venango county, Pennsylvania.[1] Dr. I. C. White included the Pithole grit in his "Oil Lake group," which he described as "composed of the *Corry* and *Cussewago sandstone* and the included *Cussewago limestone* and *shale*,"[2] and stated that the Corry sandstone, which he correlated with the "Third Mountain Sand of Venango,"[3] "passes into Ohio and continues west as Dr. Newberry's *Berea grit* outcrop."[4]

Dr. Orton thought that the Sunbury shales became very thin in Trumbull county, so that the flagging stone near Warren, which he regarded as the equivalent of the Buena Vista stone of southern Ohio and the Sharpsville sandstone of Pennsylvania,[5] came "down close upon the Berea grit." Finally, regarding the correlation, he stated: "I am disposed to believe that the Pithole grit of Pennsylvania, as reported in many borings of the region, consists of this joint product of the two systems" [the Buena Vista and Berea sandstones].[6] Later it was stated that Dr. White's "Sharpsville sandstone is our Buena Vista stone, and his Corry sandstone appears to be none other than the Berea grit."[7]

Orangeville.— This village in the Pymatuning valley on the state line is located partly in Trumbull county, Ohio, and partly in Mercer county, Pa. On the southern bank of the Pymatuning Creek, just below the bridge and dam in Orangeville on the Pennsylvania side, is a bank composed mainly of bluish-gray shales, which gave the following section:

SECTION AT ORANGEVILLE.

No.		Thickness feet.	Total thickness feet.
5.	Dark gray to bluish-gray argillaceous shales which contain some small iron-like concretions - - - - - - -	10½	22

[1] *Second Geol. Surv. Pa.*, I³, 1880, pp. 91–97 and I⁵, 1890, pp. 94, 97–105.

[2] *Ibid.*, Q⁴, 1881, p. 91. [3] *Ibid.*, p. 92. [4] *Ibid.*, p. 94.

[5] *Rept. Geol. Surv. Ohio*, Vol. VI, 1888, p. 38, and Vol. VII, 1893 [1895], p. 31.

[6] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXX, 1882, p. 174.

[7] *Rept. Geol. Surv. Ohio*, Vol. VII, 1895, p. 33.

4.	Bluish-gray sandstone weathering to a rusty color, from 6 to 8 inches in thickness	½+	11½
3.	Grayish to bluish-gray shales, argillaceous and slightly gritty containing some specimens of *Chonetes* and *Lingula*	$4\frac{5}{12}$	$10\frac{5}{8}$
2.	Bluish-gray sandstone which weathers to a rusty color, 5 inches thick	$1\frac{5}{12}$	$6\frac{5}{12}$
1.	Rather bluish argillaceous shales, which, near creek level, are more arenaceous and bituminous, containing numerous specimens of *Lingula melie* Hall and *L. cuyahoga* Hall	6	6

All of the above shales weather to a rusty color on exposure, contain fossils, are blacker than those of the lower Cuyahoga shale in the Cleveland region, and in addition contain a much larger number of specimens of *Lingulæ*. It is the writer's opinion that the above shales are in the lower part of the Cuyahoga formation and above the Sunbury or Berea black shale.

These rocks were named the Orangeville shales by Dr. I. C. White, who stated that the name was used "merely for the convenience of avoiding in this report a premature discussion of the question of its identification with the Waverly black shales of Andrews, or lower member of the Cuyahoga shale of Newberry."[1] He described it as: "A group of shales, prevailingly blue, but often rusty or reddish-brown on exposed surfaces, always more or less argillaceous, seldom exhibiting sandy layers more than 6 inches thick; and containing considerable quantities of scattered iron ore balls," with a thickness of about 75 feet at Orangeville.[2] While under the description of Pymatuning township, in which the eastern part of Orangeville is located, is the following account of the cliff below the Orangeville street bridge: "The horizon is *300 feet below that of the Sharon coal*, and therefore under the *Cuyahoga shale*. The upper portion of this exposure consists of reddish-gray shales, interstratified with thin flaggy layers; but down near the creek level the shales begin to grow much finer and darker; and just below the mill-dam fragments of a dark-bluish fine-grained shale in the water-bed are perfectly filled with *Discina pleurites* and *Lingula melie*, This can hardly be the *Cleveland shale* of Dr. Newberry."[3] In

[1] *Second Geol. Surv. Pa.*, Q², 1880, p. 63. [2] *Ibid.*, p. 63. [3] *Ibid.*, p. 160.

the succeeding report, Dr. White spoke of the Orangeville shales as "these bottom deposits of the *Cuyahoga formation* of Ohio."[1] Dr. Orton stated that "White's Orangeville shale is an equivalent of our Berea shale."[2]

Mr. W. F. Cooper, in a brief discussion of the Berea shale, states that it "varies in Ohio from 15 to 50 feet in thickness throughout the line of outcrop, and is an exceedingly persistent and well-defined horizon. In northeastern Ohio, near the Pennsylvania line, it lies immediately under the Carboniferous millstone grit; a fact of importance in the development of the Lower Carboniferous of that state, which has heretofore been misunderstood."[3] Mr. Cooper is in error in the above statement regarding the horizon of the Sunbury (Berea) shale, for on the hill and farm of Charles Troutman, about two miles north of Orangeville, the base of the Sharon conglomerate (Millstone grit) is barometrically 270 feet above the level of the Pymatuning Creek in Orangeville, at the base of the cliff of Orangeville shales.

Dr. George H. Girty in recent years has devoted a great deal of time to the study of the Waverly series, and he differs from Dr. I. C. White and Professor Cushing, who correlated the Berea grit with the Corry sandstone of Pennsylvania, in regarding it as "the equivalent of the Cussewago sandstone of northwestern Pennsylvania,"[4] the top of which, according to the *Pennsylvania Reports*, is stratigraphically about 35 feet below the base of the Corry sandstone. Dr. Girty stated: "It is doubtful if the Corry sandstone is represented in Ohio." Dr. Girty further stated that "the Orangeville shale of that region is the basal third of the Cuyahoga shale, in part equivalent to Orton's Berea shale,"[5] in which statement the writer would fully concur, for Dr. I. C. White, in his reference to the outcrops near Warren,

[1] *Ibid.*, Q[4], 1881, p. 89, and see p. 90 f.

[2] *Rept. Geol. Surv. Ohio*, Vol. VII, 1895, p. 33.

[3] *Geol. Surv. Mich.*, Vol. VII, Pt. II, 1900, pp. 286, 287.

[4] *Science*, N. S., Vol. XIII, April 26, 1901, p. 664. [5] *Ibid.*

apparently included the Sunbury shale in the Orangeville shales.[1]

After the above was written the writer learned that a test well was being drilled in Orangeville, Ohio, and he is indebted to Messrs. W. J. Apthorpe and J. D. Burnett, of that town, for information concerning it and samples of the drillings. The mouth of the well is in the creek valley above the State-street bridge, estimated as about 6 feet higher than the milldam, which would make it about 10 feet higher than the base of the shales exposed on the creek bank below the dam. It is reported that the creek alluvium is 17 feet thick in the well and at that depth shale was struck. The first sample submitted to the writer, from the depth of 42 feet, is reported as the first sand struck in the well and from the top of the Berea grit. The sample is composed mainly of light-gray silicious and very micaceous sandstone, with an occasional grain of iron pyrites, and lithologically closely resembles the Berea grit. Mixed with the sandstone chips is an occasional one of black shale, which is evidently from above the sandstone. This light gray sandstone is reported to continue to 122 feet, and a sample from 50 feet and another from between 57 and 117 feet are from a light gray, very silicious sandstone. The sample from 117 to 122 feet is composed of fine light gray to white quartz sand with some grains of iron pyrites and its bottom is thought by Mr. Burnett to represent the base of the Berea grit. Immediately below this, Mr. Apthorpe reports 3 feet of shale; but the sample from 122 to 164 feet is composed mainly of quartz sand. Mr. Burnett, however, reported that at 122 feet the drill entered a softer sand. The sample from 164 to 170 feet is composed of bluish argillaceous shale with a white streak and bluish-gray or gray arenaceous shale to thin micaceous sandstone. From 170 to 415 feet, the chips are mostly dark gray in color and apparently mainly from arenaceous shale. The data furnished by this well,

[1] *Second Geol. Surv. Pa.*, Q[4], p. 90 f., where it is stated that "here also it [Orangeville shale] is darker and even some thin layers bituminous, which goes to support Professor Orton's identification of it with Professor Andrews's *Waverly black slate* of southeastern Ohio."

taken in connection with the barometric section from the level of the Pymatuning Creek and the Sharon conglomerate, on the Troutman farm north of Orangeville, apparently show that in the vicinity of Orangeville there is an interval of about 300 feet between the base of the Sharon conglomerate and the top of the Berea grit. There is some uncertainty as to what should be considered the base of the Berea grit. If the line is drawn at the top of the 3 feet of shale, reported at the depth of 122 feet, then the Berea will have a thickness of 80 feet. The sample, however, from 122 to 164 feet is composed mainly of rather large pieces of quartz sand and is apparently from a massive sandstone. If this lower sandstone be classed in the Berea grit, then it will have a thickness of 122 feet. The well has been drilled to a depth of 1715 feet, and the deeper samples are mainly from bluish to grayish argillaceous shales, together with some from grayish arenaceous shales and thin grayish sandstones, apparently in the Erie shale. The samples showed no indication of the black Cleveland shale, so that it is impossible to give the base of the Bedford or top of the Erie shale in this record.

An examination of Dr. Orton's description of the well records of this region leads the writer to conclude that he referred all the sandstone at this horizon to the Berea grit. Dr. Orton reported the Berea grit "to have a thickness of 100 feet, or even more"[1] in the Mecca oil field to the northwest of Orangeville, in the northern central part of Trumbull county. In the wells near Youngstown, which is southwest of Orangeville, in the northern part of Mahoning county, it is given as from 150 to 160 feet thick "with a thin bed of shale interstratified about half way down."[2] While still farther south in the East Liverpool gas field, in the southeastern corner of Columbiana county, in the Ohio river valley, Dr. Orton stated that "the Berea grit ranges in this territory from 60 to 120 feet in thickness."[3] From a well near Sharon, in the western part of Mercer county, Pa., about seven miles south of Orangeville, the Pennsylvania geolo-

[1] *Rep. Geol. Surv. Ohio*, Vol. VI, p. 331.
Ibid., pp. 402, 403. [3] *Ibid.*, p. 333.

gists have reported a white, sharp sandstone, 75 feet thick, the top of which is 313 feet below the base of the Sharon conglomerate;[1] which Mr. Carll regarded as probably identical with the Pithole grit of Pennsylvania and the Berea grit of Ohio.[2]

CONCLUSION.

It has been shown in this article that the Sunbury shale is in general a well-marked and sharply-defined lithologic division, which extends from Vanceburg, in northern Kentucky, across Ohio to the eastern part of Trumbull county, and perhaps into Pennsylvania. It is usually thin, fissile, black, strongly bituminous, varying in thickness from about 6 to nearly 28 feet. The lower part of the shale is very compact and tough, splitting into thin sheets of considerable size, which are somewhat arenaceous; frequently containing some iron pyrites, and often rich in fossils, especially inarticulate Brachiopods. Near Bedford, in northern Ohio, however, it loses its decidedly black color, and is mainly bluish-gray or blackish-gray, with some blackish bituminous layers. The base of the shale is always sharply separated from the underlying massive Berea grit. At the top, wherever exposed, it is also, lithologically, clearly separated from the overlying Cuyahoga formation, although the line of contact is not so well marked and conspicuous as the one at the base. In northern Ohio, at the base of the Cuyahoga formation, are bluish-gray alternating shales and thin sandstones, while in the bluffs of the Ohio river occur 5 feet of blue to drab fire clay and shale, which is followed by 5 ± feet of brownish to bluish-gray massive Buena Vista sandstone. Perhaps in Cuyahoga county the contact between the Sunbury and Cuyahoga shales is not so clearly defined as in most of the state, while again in Trumbull county and in the eastern part of the state there are bluish-gray to blackish shales in the lower part of the Cuyahoga formation, which resemble somewhat the subjacent

[1] *Second Geol. Surv. Pa.*, Q^4, 1881, p. 70; also see I^3, 1880, Atlas, Pl. IV, Fig. 3, where the interval is given as 310 feet; Q^2, 1879, pp. 298, 303; and Q^3, 1880, p. 119.

[2] *Ibid.*, I^3, p. 93.

Sunbury shale. Still it is thought that even in this region the line of division is as sharply and clearly defined as is often the case between two formations. It appears to the writer to be a clearly marked and sharply defined lithologic division. Paleontologically, the lower portion of the shales frequently contains numerous specimens of a few fossils, principally *Lingula melie* Hall and *Orbiculoidea Newberryi* (Hall) Herrick, which may be considered the characteristic species of the formation, although not confined to it, since both species probably continue into the Cuyahoga formation.

Finally, on account of the marked lithologic character of the Sunbury shale, its sharp boundaries, its extensive, although narrow areal distribution, and its stratigraphic importance in the classification of the Waverly series, the writer would regard it as a distinct unit in the geological scale of Ohio.

On the geologic maps, based upon the *United States Topographic Sheets* for southern and central Ohio, it appears to the writer that the Sunbury shale is clearly entitled to be represented by a distinct symbol or color and given the rank of a formation. In the northern counties the shale is not always black and strongly bituminous, and the upper limit is probably not as clearly marked as in the southern part of the state.

In western Pennsylvania Dr. I. C. White has described the Orangeville shales and Sharpsville sandstone, while Professor Lesley used the provisional name of Crawford for the overlying shales,[1] all of which in a general way are synchronous with the Sunbury and Cuyahoga shales of northern Ohio. In the succeeding report Dr. White used the terms Meadville upper shales, Meadville upper limestone, and Meadville lower shales, in place of the Crawford shales,[2] and he writes me:

> The name [Crawford shale] was never used by me nor accepted, because it meant nothing. It was provisionally put in by Professor Lesley without my consent, and the following year when it was found this interval of rocks could be further subdivided in Erie and Crawford counties, it was done, and the name "Crawford shales," which I had never accepted, dropped.[3]

[1] *Second Geol. Surv. Pa.*, Q³, pp. 59 f., 61–63.

[2] *Ibid.*, Q⁴, 1881, pp. 83–85. [3] Letter, March 7, 1902.

The shales at Orangeville are dark to bluish-gray, differing as a rule considerably in structure and color from the Sunbury shale. It is evident that the black shale overlying the Berea grit, reported by Dr. Orton from many wells in northern Ohio as the Berea shale, includes more than that shale, and corresponds to the Orangeville shale of Dr. White. Some geologists believe that the Orangeville shale, comprising all the rocks on the eastern line of the state included between the top of the Berea and the base of the Sharpsville sandstone, is the lithologic unit which ought to be represented on the United States geologic maps of northern Ohio. This is the opinion of Professor H. P. Cushing and Dr. George H. Girty, and is entitled to careful consideration, especially since Dr. Girty writes that the Orangeville shale, Sharpsville sandstone, and Meadville shale "maintain themselves across northern Ohio and appear in Medina county in fairly characteristic aspect." [1]

If the Orangeville shale be accepted as the lithologic unit for mapping in northern Ohio, then the Sunbury shale will become the lower member of the Orangeville formation for that part of the state.

NOTE.—In an article entitled "The Classification of the Waverly series of Central Ohio," published in the JOURNAL OF GEOLOGY, the writer referred to the revised classification of the New York rocks by Dr. John M. Clarke and Mr. Charles Schuchert.[2]

It was intended to state, in the first place, that two principles of nomenclature which had been given, had been imperfectly observed by many geologists in their works on stratigraphical geology. In the second place it was intended to state that, on account of this more precise use of stratigraphic names, it had become necessary to revise even the classic nomenclature of the New York series of formations, in which case it was also found necessary to replace several old and well-known names by new terms. The reference to the revised New York classification was intended as a complimentary one, and as a precedent for similar revision of the classification of other states. These two ideas, however, were expressed in one sentence in a somewhat infelicitous manner which has led to some misunderstanding regarding the real meaning, and therefore the above explanation is made.

CHARLES S. PROSSER.

COLUMBUS, OHIO,
March, 1902.

[1] Letter of February 28, 1902.

[2] Vol. IX, 1891, p. 206.

THE VARIATIONS OF GLACIERS. VII.[1]

THE following is a summary of the *Sixth Annual Report* of the International Committee on Glaciers:[2]

RECORD OF GLACIERS FOR 1900.

Swiss Alps.—The retreat of the past few years is becoming more marked. There is but one glacier, the Boveyre (in the Valais), which is certainly advancing; since 1892 it has advanced 113 meters. A smaller number than last year are doubtful, and a larger number are certainly retreating. Reports have been received from eighty-two glaciers.[3]

Eastern Alps.—The Vernagt glacier, in the Oetzthal, continues its remarkable advance, and has gained 150 meters since last year. It has united with its neighbor, the Guslar glacier, and is ploughing up its terminal moraine. The ice is seventy meters thick at the point where the glacier ended in 1895; and its velocity, at one section, where it has been frequently measured, though somewhat less than it was a year or two ago, is still about twelve times as great as it was before the beginning of the advance. Measures on the Hintereis glacier gave a velocity from the middle of July to the middle of September exactly equal to the mean for the year, suggesting a constant rate for all seasons of the year. Of the other glaciers in the same general region some show a slight advance and some a slight retreat. The most easterly glaciers, which are in the Ankogl group, present a remarkable condition; of three observed, one has retreated about three meters in the last two years, and the other two have advanced about twenty meters.[4]

[1] The earlier reports appeared in the JOUR. GEOL., Vol. III, pp. 278–88; Vol. V, pp. 378–83; Vol. VI, pp. 473–76; Vol. VII, pp. 217–25; Vol. VIII, pp. 154–59; and Vol. IX, pp. 250–54.

[2] *Archives des sciences phys. et. nat.*, Vol. XII, pp. 56–69, 118–131, Geneva, 1901.

[3] Report of Professor Forel and M. Muret.

[4] Report of Professor Finsterwalder.

Italian Alps.—The glaciers of the eastern Italian Alps show a small retreat; some glaciers southwest of Savoy are retreating more rapidly; but the snow seems to be increasing in the Maritime Alps to the west, and two of the glaciers there have advanced several meters.[1]

Swedish Alps.—The summer of 1900 was very cold, with extremely large snowfalls. The glaciers of Lapland, which were the only Swedish glaciers visited, have not changed since the preceding year.[2]

Norwegian Alps.—According to Schöning, the years when grain has not ripened in Norway were 1600–2, 1632–34, 1685–87, 1695–97, 1740–42. These dates follow pretty closely the dates of cold, damp periods in Europe as given by Brückner, and the dates of advance of the glaciers of the Alps as given by Richter. In Norway, however, it is only for the last of these dates that we have any precise information regarding the variations of the glaciers. In 1742–43 the Nigard (Jostedal) advanced about forty-three meters; in 1748 it began to retreat slowly. Other glaciers showed similar variations. There was, in general, a great advance in the eighteenth century, preceded by a very marked retreat; since then there has been a small retreat on which have been superposed many minor variations. At present the glaciers of Jostedal seem to be advancing.

The glaciers of Jotunheim were, in general, advancing in the summer of 1898; since then they have been retreating.[3]

Arctic regions.—M. Charles Rabot has given a very complete account of the observations which have been made on the glaciers of the Arctics and neighboring regions, with full references to the literature, which will be of great service to future observers. His general results as to the variations of these glaciers are:

1. Before the eighteenth century, the glaciers were much less extensive than they are today, and this minimum lasted for several centuries.

[1] Report of Professor Porro. [2] Report of Dr. Svenonius.

[3] Report of Dr. Oyen, which is condensed from a very detailed account of the glaciers of Norway published in English in *Nyt Magazin for Naturvidenskaberne*, Vol. XXXIX, pp. 73–116, Christiania, 1901.

2. During the eighteenth century an enormous advance took place, greater than an ordinary variation. The glaciers invaded territory which they had never occupied during the present [geological] period. This advance was general over all the northern hemisphere.

3. During the nineteenth century the variations have not been uniform. In some regions there has been a considerable advance followed by a slight retreat; whereas, in others, the glaciers, after remaining at a maximum up to the early part of the century have since experienced a small diminution. Nowhere has the retreat been so great as in the Alps during the last fifty years.[1]

Spitzbergen.—Baron de Geer has made a map of the southern and central parts of Spitzbergen which gives an excellent idea of the large glaciers of that region. Professor Nathorst has also described and figured some of these glaciers.[2]

Greenland.—The Swedish expedition of 1899 made a large map of northeastern Greenland; which shows a great number of glaciers, including the Waltershausen which has a breadth of 13 kilometers where it ends in the fiord. Dr. Steenstrup has described a number of small glaciers occupying depressions on the mountain sides on the western coast, which are frequently entirely covered with débris; they seem to be the remnants of a greater glaciation.[3]

Canada.— All the glaciers observed continue to retreat at an increasing rate. The Victoria glacier (Alberta) has diminished slightly. Its velocity measured at two points amounts to 130 feet per year. The Asulkan glacier (B. C.) has retreated 24 feet; the Illicillewaet has retreated 64 feet and has become thinner and

[1] "Les Variations de Longueur des Glaciers dans les régions arctiques et boréales," *Archives des sciences phys. et. nat.*, Geneva, 1897, 1899, and 1900. These papers were more fully reviewed in *Science*, December 13, 1901. It is interesting to note that the same order of events has been followed by the glaciers of southeastern Alaska, namely, a long period of small extension, then a short period of great advance, and finally a general retreat, which has been going on for the last hundred years or more. "Studies of Muir Glacier," *Nat. Geog. Mag.*, 1892, Vol. IV, pp. 38, 39. "Glacier Bay and Its Glaciers," *Sixteenth Ann. Rept. U. S. Geol. Surv.*, 1896, pp. 438–40.

[2] G. DE GEER, *Om gradmatningsnatels framförande öfver södra om mellersta Spitsbergen*, Ymer, 1900; A. G. NATHORST, *Twâ somrar i norra ishafvet*, Ymer, 1900.

[3] Report of Professor A. Nathorst.

narrower. About 1,500 feet from the end a velocity of about 194 feet per year was measured.[1]

Caucasus.— A number of glaciers in the southeastern part of the chain are retreating, and a number of glacial lakes have been discovered there. The glaciers of the central part of the chain are also found to be retreating. Two glaciers on Mt. Ararat give evidence of retreat.

Siberia.— Professor Sapojnikov has published a finely illustrated book on "The Katoun River and its Tributaries" (Tomsk 1901) in which he gives a detailed account of the glaciers draining into that river. Some of the glaciers he has mapped, others he has only photographed. They are all retreating.

Turkestan.— A number of glaciers have been recently discovered in Turkestan, all of which give distinct evidences of being in retreat.[2]

Himalaya.— The great glaciers of Kanchinjanga are from 15 to 17 miles long, and descend to about 13,000 feet above sea level. They are slowly retreating. The Anglo-Indian surveyors formerly restricted the name glacier to the clear ice between the névé fields and the lower moraine-covered portions; many erroneous ideas regarding these glaciers have thus been introduced.[3]

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1901.[4]

The narrative and general papers of the Harriman Alaska expedition have been published in two handsome volumes, which contain many excellent illustrations of the glaciers. The general description of the glaciers is written by Mr. John Muir, and he notes that at the time of his first visit in 1879, the two branches of the Grand Pacific glacier and the Johns Hopkins glacier were united and presented a single ice-front; the Hugh Miller and the Charpentier glaciers were also united at that time. He estimates

[1] Report of Messrs. G. and William S. Vaux, Jr.

[2] Report of Professor Mouschketov.

[3] Report of Mr. D. W. Freshfield.

[4] A synopsis of this report will appear in the *Seventh Annual Report of the International Committee.* The report on the glaciers of the United States for 1900 was given in the JOUR. GEOL., Vol. IX, pp. 252–54.

that the Hugh Miller and the Muir glaciers have receded about two miles in the last twenty years; the Grand Pacific and the Johns Hopkins about four miles; and the Geikie, Rendu, and Carroll from seven to ten miles.

Glacier Bay, Alaska, remains so full of floating ice resulting from the earthquake of September, 1899, that steamers were unable to approach Muir glacier last summer. However, on December 31, 1901, one of the steamers made a special effort to approach the glacier and succeeded in reaching a point about a mile from the former ice wall. The captain of the steamer reports that from this point onwards the inlet was closely packed with large bergs, and that the true end of the glacier could not be distinguished. The shores of the inlet were thickly covered with large stranded icebergs fifty or sixty feet high.

Last summer the author visited the glaciers of Mt. Hood and Mt. Adams. These two volcanic cones in the northern part of the Cascade Range support eight and nine glaciers respectively. The heights of the lateral, and in some cases of the terminal, moraines show that the glaciers have been larger at no distant date, and that they are now retreating. Some of the moraines are still underlain by ice. But few of the glaciers occupy valleys; many of them lie on the mountain slopes supported by their lateral moraines, and it is evident that they have eroded their beds very little. Stations were established at the ends of several glaciers, and future variations will be shown by photographs to be taken from these stations.

HARRY FIELDING REID.

GEOLOGICAL LABORATORY,
JOHNS HOPKINS UNIVERSITY,
February 26, 1902.

Reviews.

The Carbonic Anhydride of the Atmosphere. By Professor E. A. Letts, D.Sc., Ph.D., and R. F. Blake, F.I.C., F.C.S. (Plates XVI to XVIII). *The Scientific Proceedings of the Royal Dublin Society*, 1900, Vol. IX (N. S.), Part II, pp. 107–270.

The memoir is divided and separately treated in two parts, the results of which can best be summarized under each division. The extensive review and criticism by the authors of the literature on the amount and causal distribution of atmospheric carbonic anhydride added to the widespread importance of this constituent in aiding certain geological processes, warrant a detailed review of this very valuable paper.

PART I.

Section I is devoted to the "Introduction and Methods of Determination." The first demonstration of the existence of carbonic anhydride in the air was by Dr. Black, of Edinburgh, probably between the dates 1752 and 1754. Many different processes have been employed since De Saussure's time (1796) to determine atmospheric carbonic anhydride, but only the more important ones are considered in this paper. The authors state that with the exception of several methods based on the physical properties of gases, all the processes depend on the employment of an alkali or alkaline earth as an absorbent; and the amount of carbonic anhydride absorbed is determined by one of several methods, among the most important of which are: (1) increase in the weight of the absorbing apparatus; (2) determination of the excess of the absorbent; (3) liberation and measurement of the absorbed carbonic anhydride. A rather extended review of the work of numerous investigators following these methods, in which the more essential points in each method as developed by the individual worker, are brought out and discussed in a brief manner.

Section II is a description of "The Authors' Experiments on Pettenkofer's Process as Modified by Them." A set of determinations

made by the authors of carbonic anhydride in the air of a weaving shed in a linen factory at Belfast, in which the use of the Pettenkofer method failed to give concordant results in duplicate determinations, led to the investigation of this method by the authors. The method finally employed is described in considerable detail, including the preparation of reagents, and the apparatus used are figured. A large number of tests were made on artificial mixtures and subsequently on samples of air collected in the rooms and the grounds of Queen's College, Belfast. The results are recorded in tabular form.

Section III closes Part I of the memoir, in which "The Authors' Experiments on the Action of Baryta Water on Glass and on Silica, and the Disturbing Effect of Soluble Silicates on the Delicacy of the Phenol-Phthalein Colour Reaction," are discussed.

The results obtained are of special interest. The experiments with glass were made on the greenish-white glass of Winchester quarts bottles, using a dilute solution of baryta water of known strength. 1^{cc} of the baryta water is equivalent to 0.1^{cc} of CO_2 at N. T. P. The quantitative results for different time exposures are:

After 48 hours	- - - - -	0.0021	gram of glass.
" 72 "	- - - -	0.0025	" "
" 72 "	- - - - -	0.0050	" "
" 98 "	- - - -	0.0062	" "
" 98 "	- - - - -	0.0098	" "

The action of alkalies on glass has been investigated previously by a number of workers, and the results here obtained by the authors are in accord with those of previous investigators in showing the very appreciable effect in a short time with very dilute solutions of the alkali, which increases with the time exposure.

It is of interest here to compare Emmerling's results obtained with boiling weak solutions of caustic potash (400^{cc}) in a flask of 600 to 700^{cc} capacity, whose loss in weight per hour was found to be:

0.25	per cent KOH - - -	0.0115	gram of glass	per hour.
0.025	" " " - - -	0.0070	" "	"
0.005	" " " - - -	0.0027	" "	"

In order to ascertain the exact nature of the action of the baryta water on the glass, a given amount of the $Ba(OH)_2$ solution of variable but known strength was introduced into the stoppered bottles and allowed to remain for a given number of days, when the solution

was carefully removed and analyzed by the authors. The results follow in tabular form.

	SiO_2	Al_2O_3 Fe_2O_3	CaO	Alkaline sulphates.
Weak baryta solution.....	0.0045	0.0009	None	0.0024
Stronger " "	0.0094	0.0012	None	0.0009
'Percentage composition of the glass used.....	69.95	2.57	17.21	Alkalies as Na_2O 10.27

The authors' conclusions regarding these results are stated by them as follows:

1. A weak baryta solution acts with relative rapidity on the glass of the Winchester quarts (and probably exercise an appreciable action on most varieties of glass), dissolving silica and alkalies, and smaller quantities of alumina and ferric oxide, but no lime.

2. A stronger solution dissolves more silica but less alkalies, about the same amount of alumina and ferric oxide, and also, as in the previous case, no lime.

An appreciable effect is shown by the authors in the titration of $Ba(OH)_2$ after remaining in contact with the glass; and also on the presence of alkaline or soluble silicates on the delicacy of the phenolphthalein color reaction during titration with an acid.

Similar tests conducted on silica with a weak solution of baryta water indicated a similar action as the glass. Some very interesting quantitative results are recorded.

PART II.

Part II is treated in two sections, and makes up the bulk of the memoir. More than twice the space is given to it (106 pages exclusive of the appendices and bibliography) than is allotted to Part I, which is disposed of in 50 pages. Part II consists of a review and criticism of all authentic and trustworthy data collected from all sources and arranged in tables, which bear on the amount and distribution, and the factors controlling the distribution of carbonic anhydride in the atmosphere under varying conditions. It is more than an ordinary compilation in that the data are discussed fully but briefly and the conclusions warranted are concisely stated. It is not possible

to make entirely clear the full value of this part of the report in a review, but that an invaluable service has been rendered by the authors will appear from the following general summary:

Section I considers the amount of carbonic anhydride in the atmosphere. After discussing the effects of a permanent increase and decrease in the present amount of CO_2 in the atmosphere on plant and animal life, and the several theories advanced to account for the source of CO_2 to permanently augment this amount, a table showing the amount of CO_2 in 10,000 volumes of air is given.

The arrangement of the table from left to right includes a number of columns under the following headings: "Date of Observation;" "Observer;" "Locality;" "Number of Observations;" "CO_2 in 10,000 volumes of air, including mean, maximum, and minimum;" "Variation, including absolute and percentage;" "Author." The tabulation vertically is in the order of the date of observation, beginning with the earliest (1797) and ending with the most recent (1897). It includes 124 entries, the largest number of observations included in any single entry being the mean of 566; and the number of observations recorded in the table cover a period of 100 years.

A perusal of the figures indicates that the earliest workers obtained an amount vastly too large, accredited by the authors to the methods used. In 1812 Thenard originated a method which yielded results quite close to the present ones. From this time until about the year 1870 the average normal amount of this constituent in the atmosphere was given at approximately 4 in 10,000 volumes, an amount which is at least 25 per cent. greater than that shown at present in fresh air away from cities and towns, approximately 3 in 10,000 volumes.

Section II discusses the "Causes of Variation." In attempting to review and criticise the variations in the amount of carbonic anhydride in the atmosphere, the authors justly appreciate the difficulties encountered, and they state that "not the least of these is to correctly appraise and estimate the value of the evidence brought forward in support of the different contentions which have been raised from time to time in this matter." Only a little study of the work of previous investigators is sufficient to convince one that it has taken nearly a century for chemists to correctly estimate the average amount of this constituent in the air. The figures have been reduced from 100 to 200 volumes of CO_2, in case of the earliest workers, to 3 volumes in 10,000 volumes of air in recent investigations. Two opposite views

have been held concerning the variations, championed by De Saussure and Gay Lussac. A statement of these two opposing views can best be summed up in the words of the authors.

> According to the first of these [De Saussure], considerable variations in the amount of atmospheric carbonic anhydride occur, of a more or less lasting or permanent nature, caused by natural agencies such as the seasons, influence of vegetation, the direction and force of the wind, humectation and desiccation of the soil, day and night, etc.
>
> Gay Lussac, on the other hand, was of opinion that owing to the continued movements of the air, both horizontally and vertically, practically uniform distribution or diffusion of the carbonic anhydride occurs. It must be at once granted, from the evidence which has since been forthcoming that Gay Lussac's opinion is correct to the extent that the variations are much less than De Saussure and others of his school believed and that the average amount of atmospheric carbonic anhydride is much the same under the most diverse conditions of weather, locality, season, etc.

The authors state, on the other hand, that variations of a lasting kind do occur, amounting to at least as much as 10 per cent. of the total quantity.

Variations in the atmospheric carbonic anhydride are discussed by the authors under the following headings: (*a*) Locality and local effects. (*b*) Day and night. (*c*) Influence of vegetation. (*d*) Influence of atmospheric precipitates; (1) fog and mist; (2) rain and snow. (*e*) Influence of wind. (*f*) Influence of the seasons. (*g*) Influence of cloud and sun. (*h*) Influence of height.

The figures obtained by various investigators bearing on each one of the above headings are brought together in tabular form, reviewed and criticised, and conclusions when warranted are deduced.

While the subject of variation of atmospheric carbonic anhydride has been one of long-continued investigation and a wealth of figures accumulated, the results are lacking in uniformity, and more often have been carelessly obtained, and are therefore unreliable, and very often lead to opposite conclusions. Much remains to be done in the way of careful and uniform observation and determination by reliable and painstaking workers before definite conclusions may be looked for. From the mass of figures given by the authors the tendency, however, is certainly strongly in favor of Gay Lussac's opinion, that is, the distribution of atmospheric carbonic anhydride is more uniform and the variations not so great as was formerly held by many.

The memoir concludes with two appendices and an extensive bibliography. Appendix I is entitled "On Ground Air and its Relations to Atmospheric Carbonic Anhydride," in which some very interesting figures are given and important conclusions drawn. Appendix II is on "A Comparison of the Results of Determinations of Carbonic Anhydride by Pettenkofer's Original Process, and the Method proposed by Professor Letts and Mr. Blake, and on the Errors incidental to Pettenkofer's Process." By William Caldwell.

The bibliography contains 305 entries, proportioned as follows: German 128, French 98, and English 79.

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Om de Senglaciale og Postglaciale Nivåforandringer I Kristianiafeltet (*Molluskfaunan*). By W. C. BRÖGGER. Separaftryk af Norges geologiske undersögelse No. 31. Kristiania, 1901.

THIS volume concerns itself primarily with the study of the faunas of Pleistocene time in the vicinity of Christiania, and with the changes of level which the character and distribution of these faunas indicate.

The conclusion is reached that the deep sea bottom adjacent was something like 2600^{m} higher than now when the great ice sheet was on, this inference being based on the existence of shallow water fossils at great depths in the "Norwegian sea."

At the end of the last interglacial epoch the land is thought to have been some 100^{m} higher than now, and that this epoch of elevation continued into the time of the last ice covering. As the ice of the last epoch began to melt, the land began to sink, the subsidence continuing for some time after the retreat of the ice began. At the time of the formation of the outermost moraines, the land was 100^{m} to 125^{m} lower than now. This was the time of the deposition of the older and younger yoldia clays and of the older arca clay. While the ice retreated to the second series of moraines, subsidence continued until the land was 150^{m} to 160^{m} below its present level, when the outermost moraines of the second series were formed, and 180^{m} to 185^{m} below its present level during the formation of the innermost moraines of the same series. There was further sinking as the ice receded to its third halting place, and at that time the land stood about 200^{m} below

its present level at Christiania. Just before the moraines of the third set were made, the younger arca clay was deposited. Still later the land sank somewhat more, while the ice receded to what is called its "epiglacial station;" that is, to its fifth halting place. By this time the land had sunk to about 240^{m} below its present level. Subsidence then gavé place to uplift.

Both the subsidence and the re-elevation are thought to have affected the peripheral parts of the land first, and to have extended progressively toward the center.

The author holds the view that the ice disappeared first from the highlands of Norway, and that the higher parts of central Norway were nunataks at the time of the formation of the first moraines, and that the ice was so thin as to fill only the valleys in the peripheral parts of south Norway at the time of the second series of moraines, while during the time of maximum subsidence the ice filling the Mjosen valley is thought to have found its upper limit about 480^{m} above sea level.

The molluscan faunas of the clay beds of glacial age indicate that the climate was progressively ameliorating from −8 C., or −9 C., at the time of the formation of the outermost moraines, to +2 C. at the time of maximum subsidence. The name "Christiania Period" is proposed for the time of sinking.

The shell banks and clay beds deposited during the rise of the land indicate by their character and distribution that the rise commenced in some places sooner than in others, and that it proceeded at unequal rates in different places.

The volume also includes a study of the postglacial and recent faunas. The division between the postglacial and recent is placed at the time when the elevation after the subsidence had attained 40 per cent. to 66 per cent. of all that has taken place in the Christiania region. The distribution and the character of the faunas of postglacial and recent times show that the rate of rise has been inconstant and that progressive amelioration of the climate has accompanied the elevation. The climate at the present time is, however, cooler by about 2° C. than that which obtained while the youngest of the so-called postglacial faunas lived.

An English summary at the end of the volume makes the author's conclusions available to those who do not read the Norwegian language.

R. D. S.

Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. By N. H. DARTON. From the Twenty-first Annual Report of U. S. Geological Survey, Part IV.

IN his report on the geology of the southern half of the Black Hills, Mr. Darton has given us not only a revision and elaboration of the facts previously known about that interesting region, but has added many which are new and important. The formations which he recognizes in the area are included in the following section:

Pleistocene	River gravels and alluvium.
Tertiary	Oligocene—White River beds (unconformity).
Upper Cretaceous	Laramie. Fox Hills. Pierre shales. Niobrara chalk. Benton: Carlysle. Inoceramus limestone. Graneros shale. Dakota sandstone.
Lower Cretaceous	Fuson. Minnewaste limestone. Lakota sandstone (unconformity).
Jurassic	Beulah shales. Unkpapa sandstone. Sundance (unconformity).
Triassic (?)	Spearfish Red Beds.
Permian	Minnekahta limestone. Opeche.
Upper Carboniferous	Minnelusa.
Lower Carboniferous	Pahasapa limestone. Englewood limestone (unconformity).
Cambrian	Deadwood sandstone and conglomerate.
Algonkian	Crystalline schists and granites.

Many of these names are new, and the significance of a few of the older ones has been altered, owing to the better information which the author has gathered regarding fossils and uncomformities.

Although the report deals not only with the geologic history of the Black Hills, but with structure, hydrography, and resources of the region as well, a résumé of the first topic only is here given.

Too little is known of the pre-Cambrian condition of the Black Hills to permit a discussion of it at present. The rocks of that age are a complex system of granites and schists which will require careful

study for interpretation. The area was land during early and middle Cambrian times, but toward the close of the period the sea advanced, covering most and perhaps all of the area. The Potsdam or Deadwood sediments were largely derived from the Algonkian Crystalline rocks, as evidenced by the local material contained in the basal Cambrian conglomerate. The Ordovician beds known in the northern Black Hills are not found southward, and both Silurian and Devonian are likewise absent. As to whether the region was land during those three periods or was alternately elevated and submerged, the erosion during the times of elevation being sufficient to remove all the sediments deposited during the periods of submergence, can only be conjectured. The unconformity between the Cambrian and the Carboniferous is inconspicuous.

From the early Carboniferous on through the Trias, sedimentation seems to have been continuous. During the Lower Carboniferous the region was the scene of limestone deposition in an open interior sea. Probably there was no considerable land mass in the vicinity until the Upper Carboniferous. At this time islands are believed to have existed in the neighborhood of the Laramie Mountains of Wyoming, and they probably furnished the clastic material of the Minnelusa formation. Late in the Carboniferous or early in the Permian (the lack of fossils in the Opeche beds prevents a definite location of the horizon) the waters of the area appear to have been inclosed seas, and to have suffered temporary reduction by evaporation in an arid climate. Red clays, interstratified with thin seams of gypsum, indicate such conditions. Mr. Darton was so fortunate as to find a few Permian fossils in the comparatively barren Minnekahta limestone, thereby showing with reasonable certainty that the Permian sea extended farther north and east than was previously supposed. The Spearfish Red Beds are classed as Triassic because of their stratigraphic relation to the Permian and to the Jurassic, and because of their lithologic resemblance to Triassic formations elsewhere in the Western United States. They are almost devoid of fossils. During this period, as in the early Permian, we may suppose that the region about the Black Hills possessed an arid climate and was covered by saline lakes, in which gypsum and red clays were deposited.

The unconformity between the Red Beds and the marine Jurassic doubtless represents an epoch of erosion during the early part of the Jurassic. The Sundance, Unkpapa and Beulah formations belong

rather to the later part of the period, and doubtless owe their origin to the great gulf which entered the United States from the northwest at that time. Another period of emergence without distortion of the strata followed the exclusion of this gulf, and no surely marine formations were deposited in the region until after the Dakota epoch of the Cretaceous.

The Lakota, Minnewaste. and Fuson formations were formerly not separated from the Dakota group, but they are now segregated on the testimony of the plant remains contained in the Lakota sandstone. The local unconformities and beds of coal in the Lakota indicate a condition of slight crustal oscillations near sea level. Marine fossils have not been detected in any of the Lower Cretaceous formations nor in the Dakota. The land was probably low, and frequently inundated by lakes, or brought to a marshy condition.

By the beginning of the Benton stage the great interior sea of the Cretaceous had spread over the plains, and in it sediments continued to be deposited until near the close of the period. The prevalence of fine clastic sediments was interrupted by temporary depositions of chalk and limestone in clear open waters. The retreat of the interior sea beginning in the Fox Hills stage was probably completed during the Laramie, a large part of the latter formation being non-marine. Although the Laramie beds do not occur in the Black Hills, they are now upturned like the older beds upon the west side of the uplift, and it is probable that they originally covered the whole of it.

The Black Hills dome was probably uplifted very early in the Eocene. During that epoch it was truncated and fashioned into its present general form. That many of the larger valleys date from that time is proved by the existence of Oligocene deposits even in their deeper portions.

In the Oligocene epoch a great lake is supposed to have partially surrounded the Black Hills and spread far up on their sides, leaving the Dakota hog-back ridges isolated as off-shore islands. In support of the view that the beds are lacustrine the author cites the horizontal continuity of the beds, the fine assortment of the material, and the existence of thin beds of limestone. Although much of the formation has been removed by subsequent erosion, its former extent is roughly indicated by outlines and by a superposition of drainage which allowed many Eocene valleys to drain northward through Neocene cañons cut across the old divides. After the Oligocene no extensive sediments

were deposited in the Black Hills. A further uplift of several hundred feet produced a tilting toward the northeast which gave the advantage of gradient to the streams on that side of the uplift and induced frequent captures of the headwaters of the more southerly creeks.

No traces of glaciation have as yet been found in the hills.

E. B.

SUPPLEMENTARY NOTE TO CHARLES S. PROSSER'S PAPER ON "SUNBURY SHALE OF OHIO."

A layer of concretionary sandstone mentioned in the sections on Rocky Fork, Franklin county, showing the lower portion of the Berea grit and the upper part of the Bedford shale, according to latest observations probably belongs in the upper part of the Bedford shale. In this case the concretionary layer, No. 2, of the section of the cliff below the tree on the farm of John Augen is not to be regarded as the base of the Berea sandstone, but in the Bedford shale, while the Berea begins with No. 5.

C. S. P.

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